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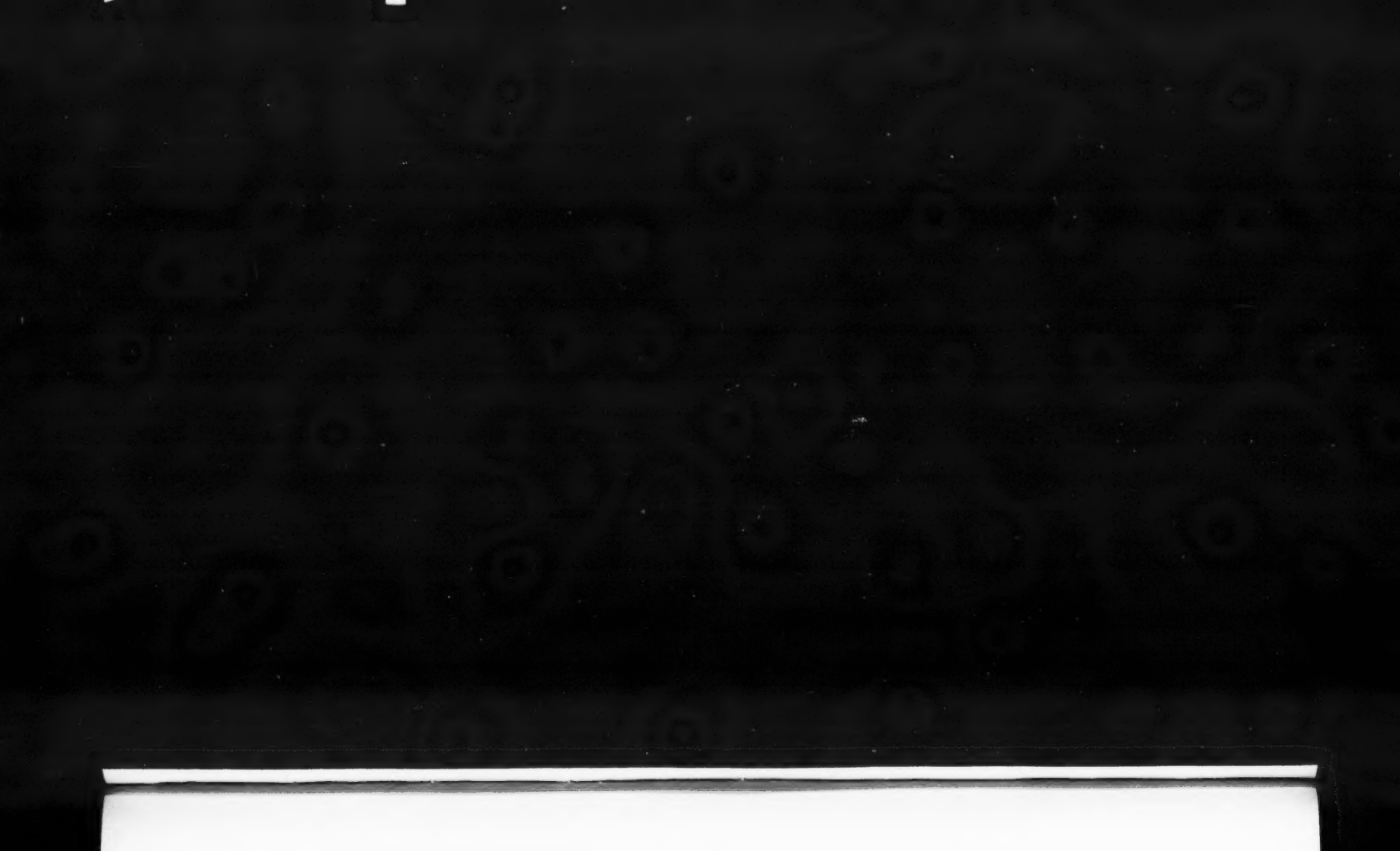

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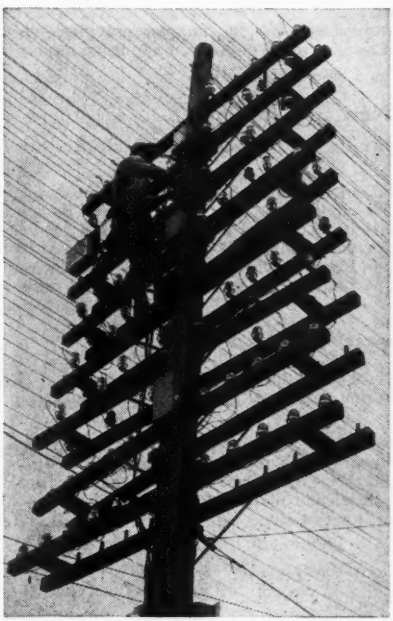

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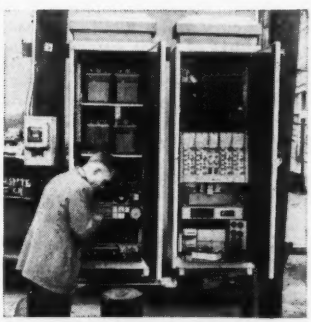

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Britain's Economic Rise and Decline and Its Implications*

By GEORGE BAEKELAND

Although our civilization may be said to have stemmed from Greece, the greatest development and enrichment of mankind occurred in Western Europe. In that small area enduring works of art and literature were produced and in it evolved parliamentary government and democracy. Modern thought, science, and the industrial arts came to us from that area. The industrial revolution originated in England, within the sphere of Western Europe.

Arnold Toynbee described the industrial revolution as the "substitution of competition for medieval regulations which had previously controlled the production and distribution of wealth." Adam Smith's "Wealth of Nations," published in 1776, advocated the doctrine of *laissez faire*—freedom in industrial and commercial life instead of regulation and restriction—a doctrine which our recent planners and do-gooders have vilified.

The woolen industry in England was carried out as a part time pursuit at home by farmers and their families. There were no overhead charges. The new cotton industry, which marked the beginning of the industrial revolution, was based on machine power and factories. Unlike the woolen industry, it required a concentration of mill hands who became renters instead of home owners, solely dependent for livelihood on the success of mills that failed if overhead charges on heavy investments were not met.

The growing needs of industry and growth of markets developed transportation and banking facilities and improved machinery. Inventions followed because England had markets, capital, coal and iron. To produce machines, machine tools had to be developed. Watt, who invented the steam engine, had to wait ten years before metal-working tools could be devised to bore cylinders of 6 inch bore and 24 inch stroke, and there were no machinists.

Ascendency of the British Empire

The beginnings of the industrial revolution were coincident with a gloomy outlook for Englishmen. They had just emerged from a long and exhausting war. But England had had her trials and setbacks at the hands of Saxons, Danes, William the Conqueror, Spain, and Louis XIV, and Napoleon was soon to try her mettle again. She was never so great as when all seemed lost, losing all her battles but the last one; unprepared for crisis, she muddled through. She was equally unprepared to admit defeat, a characteristic that has so often exasperated foreigners.

After Waterloo the economic center of the world was shifted to England. During the wars of the latter seventeen hundreds and up to 1815, England, shielded by her navy, increased her revenues, population, and manufactures, while improvements in agriculture met her growing needs.

In the 19th century Britain laid the foundation for the first world-wide economic system and became the world's leading naval, industrial and mercantile nation. The character of her people—courageous, industrious, well-balanced and

* Given at General Session of ASEE, Dartmouth College, June 25, 1952.

tenacious—contributed largely to her success in diplomacy and in commerce. The speed of Britain's rise to eminence was matched only by the rapidity of her decline, resulting from a set of conditions over which she could exercise but scant control. For her rise to the rank of foremost country she deserves great credit; for the loss of that position she cannot fairly be rebuked or criticized. Having lost the American colonies, forces beyond her control were set at work that made the change inevitable. She was an importer of food and raw materials and exporter of finished goods.

The Industrial Revolution, which began in England as already noted, gave that country a lead of about a third of a century over other nations. Since her industrial materials had to be imported with the exception of coal, she was the largest importer of raw materials and food. Obviously, it was to her advantage to embrace a policy of free trade which met her peculiar situation so adequately.

In time Britain began to import more than she exported and her agriculture declined. But returns on foreign investments and payment earned by British shipping and insurance companies were compensations. Sterling was the international currency.

Her accumulating capital became too great to invest at home. In the latter part of the 19th century British capital was employed in nearly all parts of the world. Mines, railways, and steelworks in the United States were financed, after our Civil War, with British capital and engineered by Scots and Englishmen. Hers was a world-wide economy and in industrial products other nations found it difficult to compete with her. British capital invested abroad created the roots of industry in foreign lands that were not tight little islands devoid of raw materials and hampered by a small internal consumption. The United States, unrestricted by such limiting factors, was to become a challenge to Britain's supremacy.

In such an economy as Britain's free trade became a necessity and a dogma, but its rigid application had its disadvantages. She imposed no tariff on sugar to protect her colonies, while Germany paid an export bounty on sugar. Her former lucrative West Indian sugar trade (sugar, molasses and rum) was ruined; the islands became distress areas.

Troubled Signs Ahead

In 1879 farming in England ceased to pay and thereafter the production of food declined, a period during which competition increased and exports declined. In 1840 Britain led in pig iron production. By 1897 the United States was underselling the British in London and our production of pig iron exceeded that of Britain by about 10%. *The Economist* (London) of April 16, 1898, remarked, "The fact that the United States is now able to produce pig iron and some forms of steel cheaper than this country, is a serious menace to our foreign trade in the future."

After the Franco-Prussian War of 1870 Germany became a strong, unified nation, a fast-growing industrial world power with which Britain had to reckon. Following 1870 Britain's adverse trade balance rose 20%. Her surplus declined and income from foreign investments shrank. After 1890 there was a heavy sale of foreign securities in London, especially American securities, while death and excise taxes were increased.

We were destined to become the leading industrial nation. Ours was the largest internal market in the world, with an abundance of all manner of raw materials and a rapidly growing population not dependent on foreign sources of goods. Today we possess about two-thirds of the industrial capital and three quarters of the invested capital of the world.

The need to import food to keep her population alive and raw materials to supply her industries placed Britain in a vulnerable position in time of war, a situation that undoubtedly influenced her foreign policy. With uncanny prescience and prior to the Boer war, Brooks Adams wrote, "Great Britain may be not too inaptly described as a fortified outpost of

the Anglo-Saxon race, overlooking the eastern continent and resting upon America,"[1] and he predicted that the United States and Britain would combine for their own safety, "whether or not agreeable to them,"[2] and that the risk of isolation seemed more dangerous than the risk of alliance.

Britain underrated the Boers. Mistakes and a poor showing were made at the start. These errors could have given Kaiser Wilhelm II, predominantly an aggressive military character, the hope and the encouragement for starting the first World War. That war had a crippling effect on Britain's fortunes while it did much to accelerate the strength and capacity of industry in the United States. But the first and second World Wars should not be accepted too readily as the cause of Britain's decline from her former position as the leading industrial and commercial nation; they did, however, accelerate the decline. Circumstances and destiny enabled the United States in the early part of the 20th century to reach the stature of a great nation. She was endowed with a combination of raw materials, population, foodstuffs, geographical position, climate, and a large internal market that made her ascendency possible; and the necessity to meet the demands of her large home market impelled her to develop mass production techniques.

The economic conditions prevailing in the late 19th century and the early part of the 20th resulted in a great increase in wealth and a sense of well-being and confidence. The contemporary scene was completely satisfactory, agreeable, and seemingly permanent. After the first World War many people expected the world to return to the good and comfortable pre-war days. This was the hope and conviction of many. But that war left behind it a world that they would never see again, a point of no return. Only memory could go back to a world that had gone forever.

Any hope for a return to the conditions existing in former days was shattered by the Great Depression of 1929, followed ten years later by the most far-reaching and calamitous war of all times. Eastern Europe and Russia thereafter virtually vanished from trade with the remainder of the world. Political ferment and the dominance of Russia in the Far East stifled markets. Britain and Europe lost their old supremacy and the United States gained by it. The conditions and the climate of the late 19th century lingered for a short time into the 20th century, then abruptly disappeared.

Germany's inflation following the war of 1914–1918 eliminated her debt and produced a large degree of unemployment with attendant low wages. Japan, with its cheap labor and its penchant for copying others' ideas and designs, began to undersell England, particularly in textiles, shipbuilding and light industry. Japan took some of England's lucrative trade in the Orient; her Manchurian coal was cheaper than Britain's.

Before the second World War there was a tendency in many countries to become economically and politically independent and to exploit their own resources, a situation that did England harm. She found it an increasingly greater problem to buy food from the United States because we exported more than we imported; a condition that eventually resulted in a dollar crisis for Britain.

Capital Investment Influenced by Taxation

Economists may be said to be generally agreed that to maintain an expansion of industrial production, 10% to 15% of a nation's income must be reinvested annually in new plant and equipment. In the period between the two World Wars Britain used but three per cent annually for such purpose. Her older industries were losing vitality, and unemployment followed. Her excessively high rates of

[1] P. 81, "America's Economic Superiority"—Harpers.

[2] P. 82, "America's Economic Superiority"—Harpers.

taxation on corporate and personal income, and on inheritance, were in no small measure responsible for this condition.

Since the last war, British industry has been further eroded by the combined influence of taxation and inflation. Since 1939 the level of taxation in Britain has been maintained at more than 40% of the national income.

A study made in 1935 and 1936 by the National Resources Committee, a group composed of leaders in the Roosevelt administration, indicates that the bulk of savings in the United States was made by families having incomes of $5,000 or more. It was found that the capital necessary to finance both new undertakings and the expansion of old ones was derived primarily from the after-tax income of those receiving more than $5,000 annually. In our country, this class, at the time the report was made, tended to spend $3 billion annnually for living expenses and about 74% of all their after-tax income tended to be invested in stocks and bonds.

These facts show how the prosperity of a nation is dependent upon the ability of the more prosperous sections of the population to save and accumulate capital. It is obvious that the part of income taken by government in taxes cannot be saved; and it follows that very high taxes on persons in the upper income brackets tend greatly to hamper the economic progress of a nation. The only sources of capital are the savings of individuals and corporations.

The law of diminishing returns operates in taxation and in revenue as it does in other fields. A study of taxation in the United States shows that a rate of 23% to 25% has brought the highest returns, a condition which cannot be assumed to apply solely to our own country. High taxes in England since the first World War have contributed in no small measure to a decrease in the vitality of her industrial plant; and financial history proves that when taxes consume more than twenty-five percent of national income, industrial decline sets in.

Britain's current confiscatory taxes can have no other effect than to hamper her recovery and in time they may ruin her. Taxation siphons away the money required to keep her industrial plant in repair or to equip it anew Excessive taxation is not a device to increase revenues, but to level society by dividing what capitalism has produced.

Between the two World Wars in nearly all parts of the world the price of finished products, owing to improvements in technology and to mass production, tended to decrease in relation to the price of raw materials and food which Britain was required to purchase abroad. In 1938 she imported 20% more and exported 40% less than in 1913.

Cartels and Industrial Progress

The absence in Britain of laws against monopolistic practices, such as contained in our Sherman and Clayton Acts, is undoubtedly another contributing factor in Britain's industrial decline. Competition between members of an industry in the United States is on a very different footing than it is in Britain. Our incentive to secure markets and ward off competition, domestic or foreign, is greater here, for one member of an industry may introduce a technological improvement that can be ruinous to his competitors. As we so well know, our laws prohibit "gentlemanly" and cooperative relations with competitors, here or abroad. We are forced to rely on efficiency and technological advantages over competitors. Price fixing, patent pooling, and allocation of markets are denied us. If our business relations with competing companies were cozy and friendly there would not be the pressure to employ the large proportion of technical and scientific personnel so characteristic of American industry and in numbers out of proportion with those encountered in British and European companies. Technical advances would have occurred here as they have elsewhere, but our laws regulating trade practices have made it necessary to attain the high degree of efficiency and the technical superiority that characterize American industry.

The premium we have placed on technological progress has been reflected by bonuses, pensions, employment contracts and salaries to scientists, engineers, and chemists, and on their status in the companies employing them. In many of our companies they attain important executive positions. After receiving a doctor's degree in chemical engineering or physics our students, on leaving universities, are offered by industry salaries of six to seven thousand dollars. The contrary is the rule in Britain, where technical men are poorly paid and their social status is low. The salaries of civil service scientists run from $1,800 to $3,000 a year. Research workers have to punch time cards, while senior lecturers in universities have to wash their own glassware. Such unattractive conditions have resulted in an acute shortage of scientists and technologists in Britain.

Rising Socialism

When the telegraph and telephone were introduced in England these services were taken over by the Post Office. Public utilities, too, were socialized in the last century. Britain got some of the virus of socialism rather early, a disease hard to shake off once the victim has got his feet wet. Her situation during the last war led her to resort to socialistic restrictions upon her people and economy which have not been relaxed. The creeping paralysis of Statism and the Welfare State struck England more forcibly than it did us and, to date, has gone farther. Her output per man hour has declined, as has her coal production. Without sufficient coal the underpinning of Britain's commercial power is destroyed.

The British tax load is so great that incentive is undercut by reducing the penalty for shiftlessness and reducing the rewards for doing something. Very little individual income is left available for investment or purchases.

In 1880 George Bernard Shaw and a group in England formed the Fabian Society with the avowed purpose of reconstructing the British economic system. Not interested in creating more national wealth, they sought only to achieve a leveling process, a re-distribution of wealth. The restrictive measures and high tax rates imposed in the course of two world wars did much to accelerate the blight that now pervades the British nation.

In January of this year *Time* magazine quoted Lord Beveridge, who lately spearheaded Britain's Socialism, as saying, "There has been too much leveling down. It is not posible for anyone, however hard and well he works, to enjoy the kind of income or to make the savings for old age that were easy when I was a young man. Just from where, in our classless collection of men and women, leadership will come . . . I do not know."

Britain has a badly worn out plant that has been running to capacity for years and inflated prices that add to the difculty of reinvestment in plant. Her depreciation charges are not enough at present price levels and the tax load has been increased on the earnings left after depreciation charges. Her machines are worn out and inefficient: obsolete tools cannot rapidly be replaced. Her productivity has suffered a severe loss. Her steel production in 1951 showed a decline from 1950, the only nation to show a decline, probably the result of nationalization of steel.

The last war ravaged all of Europe and Western Russia. The Far East, too, suffered from war damage and civil strife. Britain became dependent for supplies on the Western Hemisphere, which was unaffected by war or by climatic or civil crises, an area that had burgeoned under the impetus of a war economy. Between 1939 and 1944 our national income doubled. There have been two ways to obtain high produvticity and, in turn, prosperity: the former American way of rewarding incentive; and the old idea of slave labor used by Babylon, Greece, and Rome and now being tried by Russia. Britain's present Share the Wealth is in between. Incentive is killed by high taxes and her Government is not strong enough to control Labor, troubles we currently share with her if only to a lesser degree.

The locus of civilization and commerce moved westward, from China, Babylon, Greece, the Italian peninsula, the Low Countries and France, to England. Presently, economic leadership resides in the United States. Should this movement be guided by natural law—it could be coincidence—we might expect ascendency in Eastern Asia and a decline on the North American continent. The great land mass now under Russian control, in whose outpost we are presently engaged in an uneven struggle, has a vast population, a great store of natural resources, and possibly the capacity to feed its hordes: a challenging spectacle even to those who would discount the theory of natural law.

The Choice of Destiny

While dwelling on so dreary a prospect, and whether natural law or coincidence has determined the course of history, it might be interesting to speculate on what might have happened if the stupidities, the narrow views, and the injustices prevailing during the rule of George III, combined with a dislike and resentment against America, had yielded to those in England who showed wisdom and better judgment. Britain would have had America on her side during the wars with France; the War of 1812 and the bitterness that lasted for generations would have been avoided. Of course, the mere mention of such a supposition might be considered heretical, but that it did not and cannot now happen should put at ease those who sense a trace of heresy. Inevitably, industrial supremacy would have moved to North America for reasons already mentioned, i.e., climate, food, natural resources, geographical position and population but economic growth on the North American continent would in all likelihood have been less rapid nor would there have been such a rapid flood of all manner of immigrants. With control of North America it may be supposed that Britain's economic supremacy would have lasted indefinitely longer. We are reminded that our Monroe Doctrine was predicated on her naval dominance and her policing power. With the resources and manpower of North America under the British flag it is unlikely that any nation or probably combination of nations could have been a serious challenge.

Her colonial empire would have remained intact and our political status would have become akin to that of Canada. The two World Wars of this century would probably not have occurred, because Britain's growing weakness each time invited them. The Pax Britannica might be keeping order in this disordered world today. Speculation on speculation, and argument as well, could be added, but there seems to be some basis for the supposition that our victory in 1776 may not have been wholly an unmixed blessing in the light of present world problems and dangers. Britain herself came close to revolution during those days, for reasons that prompted the revolution here. The injustices that caused it and likewise prevailed in England were corrected there not long afterward.

America's Excursion in Internationalism

Our first excursion into internationalism occurred when Britain and France faced defeat in World War I. It became apparent that full American support would be necessary to prevent Germany's conquest or domination of Europe and probably Russia and the Dardanelles. Our own interests impelled us to prevent both the disintegration of Britain's mercantile empire and the economic status of Europe: we feared the prospect of an all-powerful Germany dominating Europe. Isolationism for the United States then ended but was resumed when we declined to join the League of Nations; and isolationism continued to be our policy until self-interest again prompted us to rescue our former allies from the menace of Hitler's Germany.

Had our own so-called statesmen not been so artless and simple we might have gone back to minding our own business after the second World War, to returning in larger measure to what is termed isola-

tionism but more properly might be referred to as nationalism.

Isolationism appealed to the many who so rightly sensed that we were ill-fitted for and irresponsible in foreign affairs, as witness only the irreparable folly at Teheran and the cupidity at Yalta, then the awful stupidity of our President and Secretary of State at Potsdam by giving in to the Russians while we had in the field the greatest military force of all times. Perhaps, they believed our Ambassador to Russia, who wrote the following in "Mission to Moscow": "In my opinion, the Russian people, the Soviet government, and the Soviet leadership are moved basically by altruistic concepts. It is their purpose to promote the brotherhood of man. They wish to create a society in which men may live as equals, governed by ethical ideals. They are devoted to peace." Our isolationists must have sensed that American know-how was sadly lacking in the field of diplomacy.

Our foreign policy is initiated by our presidents, party bosses raised to eminence, we usually appoint generous campaign contributors to become ambassadors, and party politicians as Secretaries of State. Is it any wonder they so often do so badly for us?

Goethe in 1831 remarked, "I hate all bungling like Sin; but, most of all, bungling in State affairs, which produce nothing but mischief to thousands and millions."

Until the early part of the last century, incompetence, bungling and corruption were as rife in English politics and administration as those evils are with us today. Patronage was abolished and a Civil Service, trained in special schools, took its place. When England's Augean stables were cleaned out, Andrew Jackson set them up in business over here. We did not ape the English that time.

Universal Sufferage and Socialism

The quality of public office in Britain improved and a debasing factor in public life was removed. The British Civil Service is perhaps the best in the world and the least affected by the faults of bureaucracy. Independent bodies of experts known as Royal Commissions are appointed to study problems and render reports prior to legislative action, a very useful system. When a government changes, hardly a hundred officials lose office—practically all public offices depend on competitive examinations.

As John Truslow Adams, the American historian, wrote, "A privileged governing class who do not have to worry about money and who are genuine in their desire to lead in a noble and independent fashion may fall below their privileges and opportunities and get out of touch with the people at large. Yet, on the other hand, a democracy, as is evident today, may show itself unable to produce capable leaders of both party and country."[1]

A factor that may have assured Britain good government for so long a time was the very gradual granting of the franchise. Not until 1884 was it extended to male heads of households. Although unqualified universal suffrage has become a fetish to many, there is no gainsaying the fact that granting to every citizen the right to vote with no other qualifications than that he or she be twenty-one years of age and not in a prison or an insane asylum has its drawbacks; no family, business, ship or farm could be expected to do well under such a system, and from all evidence no exception can be made for nations. The trend toward Socialism and the general decline in statesmanship in our own country and in others may be the result of several influences, but the advent of unqualified universal suffrage appears to share a large part of the blame.

When the executive and legislative are recruited by unqualified universal suffrage, every act must be popular and socialistic or votes are lost. The demands of the mediocre direct the acts of government. As the base of suffrage is extended so does legislative action become more debased, and the pall of mediocrity descends upon a nation. In time the frustrated masses

[1] "Empire of the Seven Seas"—J. T. Adams, Scribner.

call for a leader to curb the Frankenstein their own demands and votes have created, a political savior who will do all their thinking and acting for them. How often we hear that call in our country today, as witness only a call for a leader in an editorial in the *Saturday Evening Post* of May 3rd. Bread and circuses lead to single party governments and dictatorships, and it is likely that all countries that succumb to the folly of unqualified universal suffrage will in time go through the wringer.

Tragic Consequences of Appeasement

The second World War and its tragic effects on the world in general did more than all else to reduce Britain to the pitiable condition which currently prevails there. Had that war been prevented, as so easily it could have been with a modicum of statesmanship and political courage, unpopular with the British masses, she would today be a proud and strong nation, notwithstanding the fact that industrial supremacy had inevitably been shifted to North America.

Germany's resurgence as a great military power could have been stopped at any time in the early or middle 1930's by enforcement of the Treaty of Versailles through the League of Nations, as could Italy's sally into Abyssinia. Britain was the main prop of the League and what she did or refused to do was to determine the course of history.

When Mussolini attacked in Abyssinia and Hitler openly flaunted the provisions of the Treaty of Versailles by rearming Germany and instituting conscription, Stanley Baldwin was seeking re-election of his party by promising all things to all voters. During that campaign he strongly advocated the need for rearmament and a stronger navy but to placate the pacifists he said, "I give you my word there will be no rearmaments" and added, "There will be no war." After his party won the election he pursued a peace-at-any-price policy which prompted Mussolini to change sides by allying himself with Hitler, who henceforth was no longer isolated. When Winston Churchill took Baldwin to task for not getting Britain prepared, the latter replied, "I cannot think of anything that would have made the loss of the election from my point of view more certain."

During this critical period the United States, a signatory to the treaty of peace and its principal architect, considered it wise to have nothing to do with the foreigners. We were preoccupied with "taxing and taxing, spending and spending," too busy leaf-raking, badgering businessmen and setting up a Utopian Welfare State to concern ourselves about enforcing the peace we had won at the cost of so many lives and so much treasure We have looked upon war not as an instrument of diplomacy but as a football game; when the game was over we tore up the goal posts, threw our hats into the air and went home.

Whereas in the past insularity has protected us from attack, it likewise made us less skilled in world affairs. Our geographical position has isolated us and made our people possibly the most provincial of any of the great nations, except Russia. As a result, Americans have not understood the habits of mind, the manners, the reactions, prejudices, or ways of foreigners: our dealings with them and our diplomacy have suffered for that reason. As an example, taken within our borders, it is recognized that a Southerner is far more adept than a Damyankee in dealing with negroes; the Southerner knows, hence understands negroes.

Britain's decline and our ascendency impose on us new responsibilities and duties, unequal to them as we presently seem. The problems and perils confronting us cannot adequately be met by the calibre of statecraft displayed here to date. We have succeeded to Britain's former world position and exceeded it in nearly all respects except in governmental administration and in diplomacy. Unless we correct that weakness, historians will be writing the cause of America's decline as the course of Empire again moves Westward.

A Procedure for Teaching Fundamentals*

By FREDERICK W. ROSS

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We in engineering education are faced with this problem: With the rapidly increasing amount and complexity of engineering technical information how can we give the engineering student a good sound education? Shall we continue to cram the student with more and more specialized technical information or shall we emphasize the teaching of fundamentals?

Practical Procedures Needed

In aeronautical engineering alone reference to the college catalogue for one large university shows that the student would have to attend some four or five years after becoming a junior to complete all the specialized and pertinent upper division subjects offered. Not only would this require a total of six to eight years of college—a circumstance which would probably interest very few students—but because of the rapid obsolescence of such specialized technical information a sizable proportion of the subjects learned early in the course would even be obsolete before the student was graduated.

This situation is of course handled, generally at present, by requiring the student to elect a specialty within a specialty. This is a good expedient perhaps—but it gives the student only a narrow training and not a sound education. Also, what happens to the student who chooses a specialty that becomes obsolete or a specialty he finds impractical to pursue as his life work?

These and many similar facts have become more and more apparent in the past ten to twenty years. They pose problems we all know must be solved.

In contrast to this situation we observe that certain fundamentals are basic to all engineering fields and that these fundamentals have a much longer period of active useful life and more generally outlast the engineer himself. In consequence we ask: Shall we emphasize the teaching of these fundamentals rather than continue to cram the student with more and more detailed information?

This question may be viewed in two ways:

(1) Should we emphasize fundamentals? and

(2) If so, how can we do it?

Considerable has been said and written on these two questions, principally the first, showing why it is advantageous to teach fundamentals. While perhaps we don't all agree with all that has been said, I believe that we all, more or less, agree with the general idea. Yet, we ask—How can we, in a practical way, teach fundamentals effectively and yet turn out technically sound engineering graduates?

I believe the entire problem even though excellent in principle, will stand or fall depending on whether a good practical way of doing the job can be found or not.

Present Curricula Preferable

There are two ways of approaching the problem of teaching fundamentals:

(1) To rearrange the subject matter (curricula) to fit in additional courses involving fundamentals, or

* A paper given before the University of Detroit Section of The American Society for Engineering Education at the University of Detroit, April 4, 1952.

(2) To work out new methods of teaching to emphasize fundamentals within the framework of present curricula.

The second approach has three imporant advantages:

(1) The fundamentals can be made more realistic and interesting to the student if taught in surroundings as near the real thing as possible, (2) no immediate change in administration of curricula need be made, and (3) by making the changes within the framework of present curricula any necessary changes in curricula can be made gradually as the work evolves rather than by requiring drastic immediate changes. It seems reasonable to expect that any practical solution to the problem of teaching engineering fundamentals must be carried out at class room level between instructor and student in terms of subject matter already deemed, by previous experience, to be important enough to be included in present curricula.

Many of the elements discussed here are already well known. It is felt, however, that the manner in which they are used offers improved effectiveness. For that reason I should like to pass along my experience to date in trying to evolve a procedure for emphasizing the teaching of fundamentals within the framework of present curricula.

Results to Date

About a year ago, while teaching a course on airplane stability and control, it occurred to me that here was a course which might lend itself advantageously to the emphasis of fundamentals. The subject matter involves the most advanced aerodynamics interrelated with rigid body dynamics in six dimensions. The complete solution of such a problem involves a system of six differential equations with complicated variable coefficients.

Although this is a senior course, the subject cannot be handled in ten weeks even if the students had the necessary mathematical and aerodynamics background.

In this course then we have a choice of

(1) giving the student a mass of miscellaneous information with no more than a vague idea of what it is all about, or
(2) we can try to give him a sound fundamental foundation to build on.

Knowing from previous experience that the first approach, the descriptive approach, left much to be desired, I ventured to try the fundamental approach.

The results of this first attempt were like this: Rather than gaining a nodding acquaintance with a mass of detailed stability information and a rather vague notion of how it is all related to the whole stability problem,

(1) Over two-thirds of the class showed a fairly mature grasp of the fundamentals involved.
(2) Two students, except for minor numerical errors, completed a difficult final exam for which the instructor took nearly the entire period to work.
(3) Only two students were lost in the details (as is generally the case for the majority of students with the usual more descriptive presentation).

These results seemed sufficiently encouraging to go further into the matter. Since then constantly improved versions of the procedure have been tried in six or eight different classes including aerodynamics, theory of compressors and turbines, and fluid mechanics as well as the course on airplane stability and control.

Outline of Procedure

The procedure is simple and—a point of interest to all instructors—easy on the instructor—less detail need be prepared.

The teaching of fundamentals must start with the instructor. He must break the subject down into the most elementary essentials and show how the essentials are related to the many ramifications he in-

tends to illustrate. This may require a slightly different view of the subject, but along with this and what detailed engineering information we all have from our own experience, the instructor is well equipped to apply the method.

The fundamentals must be presented in the simplest, clearest terms possible for the stature of the students. If the instructor has a thorough grasp of the subject this approach will be the easiest to present; if not, then such a preparation will add much to his understanding of the subject and hence to his ability to put it across.

The method as evolved to date may not be directly applicable to some courses such as those involving mainly descriptive matter or to large lecture classes. Perhaps some aspects of the procedure could be adapted in such cases, however.

Briefly the method may be outlined as follows:

1. Student Participation
   (All analyses, including newly presented subject matter, theory, and problems, are accomplished entirely by class discussion—mainly by question and answer method.)
   A. Orientation
      (Accurate but informal definitions are presented in terms of students' background including previous engineering, science, and mathematics courses *as well as everyday experiences.*)
   B. Follow-up (Feedback)
      (By question and answer find out if the students are with you at all times—if not, slow down until you are together.)
   C. Repetition of Fundamentals and Their Applications
      (Every time a fundamental is needed in a derivation or a discussion ask a student to furnish it and to trace through its implications.)

This student participation can usually be conducted as a round-table discussion. This informal approach opens the student to the subject and removes the mental block often present in more formal presentations. It gives him practice in thinking in terms of fundamentals much as he does other things in life and in addition gives him practice in extemporaneous speaking. It provides a way for him to gain confidence in his own ability to cope with problems by using his own mental faculties rather than by leaning on books or instructors.

2. Programming (not scheduling)
   A program is an outline or *order of events* to be pursued, while, on the other hand, a schedule is a statement of *time of projected operation.* (Rather than hurry from one subject to the next to meet a given time schedule we should take the important material in program order, i.e., "finish" each topic before starting the next. At a musical concert each selection is finished before starting the next—certainly an education is more important to the student than the playing of a piece of music. We should try to cover each step well before going on. It is more important to gain a better understanding than to cover more subject matter. In applying this, of course, judgment must be exercised. Sufficient time cannot be allowed for unusually slow or careless students, and in some beginning subjects understanding is not always possible the first time a subject is presented. It certainly applies, however, to most upper division courses.—This is discussed further later.)
3. Analysis Breakdown
   Neat systematic summary
   (It is preferable that all items in a, b, and c below be given in terms of some kind of "short hand" notation or in terms of symbols or mathematical relationships where possible so that the larger logical steps can be visualized more readily without being lost in too many details.)
   a. Items given directly (direct knowns)

b. Items implied (indirect knowns)
c. Unknowns

4. Distinguish the Concepts Involved

a. Physical concepts
b. Mathematical aspects
c. Units problem
(By the use of symbols appropriate to the problem each problem or derivation should be divided into smaller steps which are thus each shown in a simple mathematical relation to the whole problem —see example cited later for further explanation.)

5. Closed Book Examinations
(Closed book examinations are preferable. The student should learn to think by himself without leaning on a book or answer book, or an instructor. It is felt that this is important in helping the student gain confidence in himself.)

Correlated Principles

In order to apply the method more effectively the following important principles should be well understood:

1. Cross Roads Principle
The class room is a cross road—every student, including those having had the same courses, comes to class from a different "mental" route. They usually have much in common but still their degree of understanding is often widely different.
2. Vague Notion vs. Working Understanding
The distinction between these two items must be constantly kept in mind. Engineering (both design and analysis), like thinking, is an art. Anyone can get the vague notion of how to play the piano in a few hours. To become a concert artist requires years of concentrated effort and practice. So it is with engineering—the student must *practice* the use of fundamentals in the solution of important engineering problems before he can really make use of them in the solution of difficult problems.
3. Latent Ability and Knowledge
Most students have much ability and knowledge lying dormant in their minds. If these latent abilities can be drawn out a few times by, say, the question and answer procedure, or by closed book examinations, the students learn to appreciate what they can do for themselves. Usually their interest and enthusiasm rise accordingly, and once they find it out they develop much more rapidly from their own increased interest.
4. Mental Economy Principle
It has been said that there is no limit to what most people will do to avoid thinking—consequently almost everybody is looking for some special short cut formula—some easy way out—to avoid thinking. By examples, drawn from problems and experiences, the students can be shown, especially in the complex engineering problems of today, how much they can save in time and effort by good sound analysis—*the real short cut.*
5. Reflection (or Follow-through)
All students should be encouraged to appreciate that when the first answer to any problem is obtained, the problem is only about half finished. It must be checked—rearranged—presented. It must be reviewed to gain an over-all perspective of the principal points of concern. In the class discussions this is done by repetition (Part 1 c. above).

Discussion of Method

The use of student participation, involving orientation, follow-up and repetition, and the use of programming rather than a time schedule, will in some cases require additional time. Experience has shown that although most classes may be considerably behind by mid-term, sometimes, and particularly in senior courses, they go farther before the end of the term. Because of the basic nature of engineering fundamentals and analytical methods to all engineering subjects, it seems reasonable to expect that if students study using these methods for several successive

courses much momentum will be gained so that any loss which may be experienced at first will be more than regained before they are graduated.

Two examples will be discussed to illustrate some of the more important points of the procedure.

First, let us consider part 3 b. of the Analysis Breakdown, entitled "Items implied" or "Indirect knowns." Such items include all pertinent general principles implied as well as all pertinent mathematical relations implied. To illustrate the former, consider the following problem: an airplane glides from a height against a headwind. What is the maximum horizontal distance the airplane can glide in terms of known aerodynamic characteristics? This problem usually stumps even the best of students—until they can appreciate and understand the one simple fact—that the airplane flies in the surrounding air (i.e. relative to the air) and that any aerodynamic analysis must be set up in terms of the surrounding air rather than the ground. Once this simple fact is really understood the problem is easily solvable. Then the student can readily see why—although the airplane flies in "still" air, which is moving past the earth, the magnitude of the headwind requires a change in the manner in which the airplane must be operated in order to glide the maximum horizontal distance.

Second, as a further example of "Items implied" and to further illustrate the distinction between 4 a. "Physical concepts" and 4 b. "Mathematical aspects" as well as the "Units problem" (4 c.). Consider a fluid flow problem involving energy balance. Given: a fluid flowing in a conduit from station (1) to (2)

The main "Physical concept" is very simple:

By the law of conservation of energy—the energy at (1) plus heat or work added less heat or work removed is equal to the work at (2). Any junior student who can count money can understand this—he has so much money in his pocket, he spends so much, he earns so much, he has so much left. Have him write it down in terms of the energy in the fluid something like this: if e_1 is the energy in the fluid at station (1) and e_2 at station (2), then

$$e_1 + \text{heat or work added} - \text{heat or work removed} = e_2.$$

In any particular application each of these quantities must be evaluated. For example, in an adiabatic expansion no heat or work is added or removed, hence $e_1 = e_2$; in a compressor work energy is added to the fluid, no heat is added or removed, hence $e_1 + W = e_2$; in a turbo-jet engine heat is added by a burner and work is removed by a turbine and added by a compressor, thus

$$e_1 + Q - W_t + W_c = e_2. \qquad (1)$$

It is important that this simple concept be determined and clearly understood before attempting to evaluate each separate item. Thus the major items which enter into the problem and the manner in which they enter can be clearly understood without complication of the details of evaluation of each major item.

The next step is the evaluation of the major items. These can often be broken down into smaller units. For example, the energy in the fluid at station (1),

$e_1 =$ (kinetic + gravity potential + pressure potential internal + chemical + nuclear + etc.) energies.

The detailed mathematical expression of each of these items is a separate problem and need not be confused with the main problem. To illustrate this aspect consider a problem involving only the first four types of energy. Then,

$$e_1 = \tfrac{1}{2}v_1^2 + z_1 + p_1/w_1 + Ju_1. \qquad (2)$$

The student need not consider the matter of units in the problem until he reaches

this point. Thus any confusion of units is separated from the main problem.

The substitution of these detailed quantities into a relation such as eq. (1) is simple and almost trivial, and all students can handle it immediately, and hence the problem is like an open book, easy to visualize, easy to check. The student then by the use of simple algebra derives his own equation for this particular problem as

$$\tfrac{1}{2}v_1^2 + z_1 + p_1/w_1 + Ju_1 + Q + W_t - W_c = \tfrac{1}{2}v_2^2 + z_2 + p_2/w_2 + Ju_2. \quad (3)$$

No emphasis is placed on this resulting equation. In the class each problem is started from the simple fundamental relation which is the basis of equation (1). *In this way the student understands that equation (3) is the algebraic solution to a particular problem rather than a formula.* He has the understanding and is then able to set up similar problems for any circumstance required rather than to use a general formula similar to equation (3). By "opening the problem up" in this way, such things as sign conventions which are easily susceptible to error, and checking difficulties are avoided—and a very important point—the student has an effective simple way to check the problem, either in the manner of application of the various terms or in the units.

The essence of the analysis then is to analytically "open the problem up" so that the student can see the main problem and so that he can isolate the details that cause trouble. Thus he can concentrate his effort on the difficult parts after removing the masking effect of the things he knows. Thus it is usually found that the difficult parts aren't as difficult as at first appears, as is usually the case when he tries to solve the whole problem by "insight" or at a glance or by a formula.

When presented in this "open" analytical way, in the friendly round table discussion method, illustrated by numerous examples, the student soon finds out how much better he can understand the problem, how much more easily he can check his results, and how easy it is to trace down errors and to make modifications to fit other problems—then he begins to gain confidence in his own abilities—and can begin to stand on his own "mental feet."

This manner of analysis has another important aspect. It prepares the student to fit into a supervisory capacity.

If the energy problem just discussed were a problem which required a large number of persons, then the student who has a working understanding of these procedures is in a position to supervise or administer such a problem most effectively. Thus the chief engineer sets up the main problem (represented by the relation $e_1 + Q - W = e_2$, e.g.). He then arranges his organization to have one division handle each part (represented by e_1, Q_1, W_1 and e_2 respectively). Each of these divisions headed by a divisional supervisor in turn can separate his division into smaller departments (e.g., e_1 can be separated into kinetic, chemical, etc. departments—each with a department head). As in the analysis of problems, so also in the administration of larger problems by "opening the problem up" by analysis the difficult phases can be separated from the simpler. Thus the administrator can appoint the more capable and better qualified persons to handle the more difficult phases but need not have such highly specialized persons for all parts of the problem. He can concentrate the effort where needed.

The importance of analytical experience gained in this way to the administration of technical problems it is believed is invaluable, and should help prepare the way for administration in broader fields.

Summary

In summary, it is believed the student who can analyze problems in this way should be prepared to become a competent engineer—he knows how to go ahead by himself—he develops self-confidence, he starts to think for himself, he learns how to separate the unimportant details from the important and difficult issues. It is believed that this is what we want to give the student—a good sound engineering education.

The Status of Engineering Economy*

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Why and How of the Survey

In discussing the problem of how to encourage more schools to teach Engineering Economy and to get more students to study the subject, the Engineering Economy Committee asked that a survey be made of the present status of the subject. A preliminary questionnaire was sent to each school offering four or more years of engineering education as listed in the Educational Directory published by the U. S. Office of Education. This first questionnaire, among other things, requested the name of the individual in charge of the teaching of Engineering Economy in the event that the school offered the subject. A second questionnaire was sent to this individual to get the complete details on the manner in which the subject was taught. In each of the questionaires, the subject of Engineering Economy was defined as "the body of principles involved in making a wise choice between engineering alternates." To give further substance to the definition, the questionaire stated, "The course usually includes a study of prospective rate of return, interest, annuities, depreciation, financial statements, comparisons on the basis of present values and expected annual costs, replacement problems, etc."

Statistical Results of the Survey

To get a broad picture of what engineering colleges were recommending to their students to acquaint them with the principles of business practice, the questionnaire asked the approximate percentage of students taking work in the following four fields: Engineering Economy, Economics, Accounting, and Business Principles. Table I indicates the results of the returns from 122 of the 150 schools contacted.

The following facts have been gleaned from the returns from the 57 schools that reported that they taught Engineering Economy and who gave sufficient information. Table II indicates the frequency with which Engineering Economy is required or frequently elected in each of the 18 curriculums.

Table II gives some interesting information when you note the ratio of the number of schools *requiring* Engineering Economy to the number of schools *offering the subject as an elective.* It is evident that the Industrial Engineers with their 26 to 1 ratio value the subject very highly. The Civils also hold it in high esteem with a ratio of 33 to 10. The Electricals and Mechanicals appear to regard it as important but not essential since their ratio of required to elective is approximately 5 to 4. It is evident that those schools who have organized a course in Engineering Economy do regard it as important since the totals indicate it is required in 152 curriculums and elective in 90 curriculums.

The most popular text appears to be Grant's "Principles of Engineering Economy" with 24 courses in which it is the only text, and 5 courses where it is used in conjunction with some other text. Four other texts are closely grouped as also popular. Woods and DeGarmo was used

* Presented before Engineering Economy Committee of the American Society for Engineering Education, June 26, 1951, Lansing, Michigan.

in 7 courses and in one other course in conjunction with another text. Thuesen was indicated as the sole choice in 6 courses and as a joint text in 3 others. Canfield was adopted in 5 courses and Bullinger in 4 courses with a fifth case where it was used jointly.

The second questionnaire also asked for a statement of the prerequisites for a course in Engineering Economy. The most popular prerequisites were: Senior standing (16), Junior standing (11), and principles of economics (9). Several schools related Engineering Economy to earlier courses in Accounting or Industrial Management. Columbia specified calculus, accounting, and corporation finance as prerequisites. From the results of the questionnaires I presume that much can be done to more effectively relate the study of engineering economy to the study of engineering design, business principles, accounting, statistics, and economics.

The average Engineering Economy course is equivalent to 3.7 quarter credits when we consider only those courses that are strictly limited to the field of Engineering Economy. One school presents the course in the sophomore year, 11 in the junior year, 38 in the senior year, and 1 in the 5th year of a 5-year curriculum. The philosophy behind the 4th year place in the curriculum is that the seniors will be getting a taste of design problems in some field of engineering at that time. However, a number of schools are now convinced that the general principles of Engineering Economy should be presented in a fairly elementary manner at an earlier date so that the student will be better prepared for the transition from the study of science to the study of engineering design.

TABLE I

AVERAGE PER CENT OF STUDENTS TAKING ONE OR MORE COURSES IN EACH OF THE FOLLOWING SUBJECTS

Subject	Average %
Engineering Economy	40.6
Economics	92.1
Accounting	23.4
Business Principles	25.4

TABLE II

NUMBER OF SCHOOLS IN WHICH ENGINEERING ECONOMY IS REQUIRED OR FREQUENTLY ELECTED FOR EACH CURRICULUM LISTED

Curriculum	Number of Schools Requiring	Number of Schools Electing
Aeronautical	9	6
Agriculture	3	5
Architectural	3	4
Ceramics	2	2
Chemical	9	10
Civil	33	10
Electrical	20	16
Engineering Physics	1	4
General	5	2
Geological	4	0
Industrial	26	1
Mechanical	24	19
Metallurgical	2	2
Mining	3	1
Petroleum	3	3
Sanitary	4	1
Textile	0	1
Other Curriculums	1	3

The average engineering student becomes intrigued with the problem of obtaining "exact" numerical answers and it is healthy for him to make an early acquaintance with the fact that the most difficult type of problem is that of making a choice between several answers, none of which is "exact."

Interpretation of Objectives

What are the real objectives of Engineering Economy and how important are they in Engineering Education? If only 40 per cent of our engineering students should have an introduction to the principles of wise and economic choice, how are we going to choose the right 40 per cent? Or should *all* engineering students have an introduction to Engineering Economy? Or are we on the wrong track altogether, and should we return to the policy of teaching the fundamentals of science, a little about the techniques of modern design, and nothing else?

It seems obvious that present trends in engineering education are toward breadth. A number of engineering educators in

replying to the questionnaires emphasized this fact and particularly the fact that Engineering Economy was designed to accomplish this purpose. A typical statement was that of Professor J. F. Manildi, University of California at Los Angeles, who stated, "It is our strong feeling that our course in Engineering Economy is indispensable in the engineering curriculum. We feel that an engineering graduate is not properly qualified to handle everyday engineering problems on the job unless he has an appreciation of the influence of the economics of the situation on the technical aspects of the problem." This does not indicate that a course in Engineering Economy will broaden a student to the extent that is desirable, but it does indicate that it is an opening wedge in getting the engineering student to consider the value of other than purely technical studies.

Evaluation of Present Practice

The average course in Engineering Economy does seek to acquaint the student with enough of the vocabulary of accounting, business practice, finance, etc., so that he can work intelligently with management. In addition, the course gives the student some techniques of analysis that will enable him to deal with technical problems in which first costs and continuing annual costs are factors. All of these studies are directed at helping him understand the problems of an individual business. He may even get a little glimpse of how factors such as taxation, price levels, etc. affect the individual business and this may give him some curiosity in regard to these factors.

It is my belief that the study of Engineering Economy with its concern for the problems of the individual business unit is much more elementary and basic than a study of the topics included in the average course in the Principles of Economics. I agree that Economics has greater breadth than Engineering Economy if each course actually teaches what it proposes to teach. I also agree that an understanding of Economics is a prerequisite to a stable functioning of a democracy. However, my experience in dealing with students who have studied economics in their sophomore or junior years is that they have gained a very trivial comprehension of the material included in Principles of Economics.

A much more logical plan for effectively broadening engineering students is to teach them something about the operations of an individual business enterprise before we attempt to help them understand our economy as a whole. Good teaching in practically any field seeks first to describe units and then to describe systems. How can a student understand a system until he has acquired at least a good acquaintance with the components of the system. Why don't we teach Engineering Economy in the junior year and Economics in the senior year, or at least teach the courses in this order?

From the standpoints of motivation and effective teaching, this arrangement seems much more desirable. A junior is eager to engage in a discussion of problems that appear to be the type that an engineer will be called upon to solve. The economy considerations of engineering problems can be presented as something of a shock to his vital concern with physical solutions. If Engineering Economy is taught in a challenging manner, the students' curiosity should be aroused to learn more of the broader problems such as might be presented in Principles of Economics. Then when a student hears a discussion of taxation he appreciates how the proposed change in taxation will affect the decisions of an individual business. To the author, it appears vital that engineering colleges require a course in Engineering Economy that will provide the introduction to the economy problems and business vocabulary described above. As a very minimum plan of action, engineering educators should instigate a thorough study of the optimum arrangement for introducing engineering students to business practice and the principles of economics.

Variations and Innovations

Some interesting work is being accomplished by institutions that are attempting to integrate the teaching of Economics and Engineering Economy. However engineering educators will have to experiment even more if we want to uphold the engineer's reputation for willingness to engage in practical research in comparison with the reputation of our cousins the economists. This past year they published a report of their committee on The Teaching of Undergraduate Economics clearly emphasizing the need for improving the teaching of their subject and indicating a genuine willingness to completely reorient their program.

Typical of this willingness to try new methods is this statement of the Sub-Committee on the Study of Economics in Schools of Business: "We believe that conventional economic theory courses are not well-suited to a business student. He has no obvious interest in or motivation toward such courses. Therefore, to teach the considerable amount of economic theory which a business student should learn, a device must be found for relating the subject to his interests and objectives. This we believe can be done by centering the study around the business enterprise." They have several recommendations that would appeal to engineering students at least as much as to students of business: "(1) Analytical methods should be emphasized, as against descriptive, legalistic, approaches. The ultimate objective is to teach students to think intelligently about the problems they face. They can and usually must learn most of the facts of an individual business or industry, on the job, and (2) Historical studies should not be neglected. . . . Economic history provides perspective and may enable business men to balance short-run and long-run considerations." This sub-committee went on to make the specific recommendation that the economics taught to business students include the "economics of the business enterprise," meaning the economic problems faced by an *individual* business organization.

Economists have not only been *discussing* the problem of achieving effective teaching of their subject to all types of college students, but they have been conducting classes on an experimental basis. They have also published a number of new texts that seek to approach the subject in a more interesting manner. "Business Economics, Principles and Cases" by Alt and Bradford, "The American Economic System" by Newbury, and "Managerial Economics" by Joel Dean should be reviewed by all teachers of Engineering Economy.

This past year has also witnessed an increased interest on the part of engineering registration officials in requiring candidates for registration to demonstrate their ability to analyze engineering economy problems. Professor Matchett of Illinois Tech indicates that a section of the registration examination in Illinois is now devoted to Engineering Economy and that as a result several more engineering departments are considering requiring the subject in their curriculums. Professor R. C. Gorham of the University of Pittsburgh reports that two questions on Engineering Economy are now included in every registration exam in Pennsylvania. Professor Arthur Lesser of Stevens Institute of Technology described in some detail the situation in New York where each candidate must answer 3 out of 5 questions on the Economics of Engineering and Practice.

Employed persons are now being offered Engineering Economy and refresher work in this field. There are thousands of engineering graduates who never were exposed to the subject who are now moving into positions where they must make, or least assist in making, decisions regarding engineering economy problems. In many respects Engineering Economy is a natural subject for continuation study. One idea stressed by leading business executives replying to a questionnaire dis-

tributed by the American Economics Association, was that "many subjects can be understood and knowledge of them acquired better after graduation than before." While the principles of Engineering Economy are readily understood by undergraduates, appreciation of its usefulness should increase rapidly as an engineer gains experience.

Conclusions

The areas in which we should sell our subject are so vast that we must utilize every means at hand if we are to make appreciable progress. My own interpretation of this survey is that our biggest opportunities are:

(1) To insist that Engineering Economy is basic to engineering and should be required in the engineering curriculum.
(2) To explore the idea that it is more basic than a study of the national economy as a whole, and should be presented prior to general economics. This recommendation *does not* mean the elimination of economics, but it does suggest that economics can best be learned *after* the student has studied the principles by which an individual organization plans its economy and investment programs.
(3) To explore the means for integrating Engineering Economy, or at least coordinating it, with the teaching of economics.
(4) Te increase the availability of evening or in-service courses designed for employed engineers who want to learn more of engineering economy techniques and who are motivated to learn more of the relationship of their problems to those of the national economy. Such a venture should definitely be a cooperative venture of engineers, economists, and teachers of business principles.
(5) To increase our efforts to improve the quality of teaching.

The author wishes to thank the members of the Committee on Engineering Economy for their interest, suggestions, and counsel. The deans, administrative officers, and teachers of Engineering Economy who answered the questionnaire demonstrated a willingness to help that was far beyond what the author expected. Whatever value this paper has is primarily the result of the enthusiasm and cooperation of those who furnished the material and ideas.

In the News

The program of the second Convention of the Panamerican Union of Engineering Associations, more commonly referred to as **UPADI,** held its Convention on the Tulane University Campus August 25–30, 1952. The ASEE was represented by Dean L. J. Lassalle of Louisiana State University and Dean S. S. Steinberg of the University of Maryland. One of the speakers was W. R. Woolrich, President of the ASEE, who presented a talk on "Engineering Education in the United States."

The 30th, 31st, and 32nd basic courses in radioisotope techniques in research will be offered by the **Oak Ridge Institute of Nuclear Studies** on January 5, February 2, and March 2, 1953.

Application blanks and other information on the one-month courses may be obtained from Ralph T. Overman, Chairman, Special Training Division, Oak Ridge Institute of Nuclear Studies, P. O. Box 117, Oak Ridge, Tenn.

The Undergraduate Thesis in Chemical Engineering at M.I.T.

By ALAN S. MICHAELS

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I. *Educational Objectives of the Undergraduate Thesis*

The senior thesis has been an important requirement of M.I.T.'s undergraduate program for a great many years. Until October of 1943, the thesis was prerequisite to receipt of the Bachelor's degree in all fields of specialization; during the latter war-years, however, when a large percentage of the student body was in uniform and being trained for technical responsibilities in the military services, the Faculty voted to permit substitution of professional fourth-year subjects for the thesis. This regulation remained in effect after the end of the war, and fell under the scrutiny of the Educational Survey Committee during their deliberations in 1948–1949. The Faculty Committee on Undergraduate Policy, which came into being soon after completion of the work of the Educational Survey Committee, deliberated on this issue, and in March, 1951, reported to the Faculty that it favored a return to the thesis requirement. Only recently was this recommendation brought up before the Faculty for action; in February, 1952, it was voted to reinstitute the thesis as a formal requirement for the Bachelor's degree. During the eight-year period from 1943–1951, many departments (including Chemical Engineering) rigorously adhered to the thesis requirement, whereas others freely authorized course-substitutions. The records show that only about 62% of June, 1950, and June, 1951, graduates submitted theses, although the non-thesis graduates were largely confined to those (relatively few) departments whose administration believed the interests of the students to be better served by course-substitutions.

In presenting its motion before the Faculty, the Undergraduate Policy Committee implemented its recommendation by enumerating what it considered to be the major educational objectives of the undergraduate thesis:

"The senior project or thesis should provide the participating student an opportunity to:

1) Deal with a problem of some significance and be responsible for making decisions concerning it. Formulation of the problem to be undertaken and the devising of methods of attack should be involved.

2) Gain experience in seeking out information pertinent to the project.

3) Discipline himself to plan the use of time and facilities.

4) Integrate the various subjects of study and other prior experiences; coordinate and consolidate activities which may cross the boundaries of two or more professional fields of endeavor.

5) Get experience in the formal presentation of results including a carefully prepared written report.

6) Meet with staff members on an individual basis at a professional level.

7) Develop further his creative talents."

The committee also delineated the scope of the thesis to be "a comprehensive problem, involving not less than 9 credit units, which requires initiative, creative thought,

responsible decision and action for successful progress towards a solution." An individual problem was believed preferable, although group-projects were recognized as desirable in certain cases if the individual participants could be separately evaluated. A thesis might involve one or more of the following kinds of endeavor: (1) laboratory research, (2) design, (3) library research, (4) field investigation, (5) theoretical investigation, and (6) any other effort demanding responsibile individual student-contribution. An undergraduate thesis need not constitute an original contribution to knowledge, the committee believed, as long as it demanded creative thinking on the part of the student.

In Chemical Engineering at M.I.T., the above-mentioned objectives and scope of the undergraduate thesis have for so long dominated the educational philosophy of the department that it is difficult for most of us to see the necessity for their restatement. In essence, the guiding principle behind Chemical Engineering education, as established by W. H. Walker and W. K. Lewis, has been to prepare students to face new and unfamiliar situations with professional competence; the thesis, therefore, is but a continuation of a principle to which the undergraduate has been exposed since his first contact with Chemical Engineering as a field of specialization. As a consequence of this early training, the Chemical Engineering undergraduate is, we believe, peculiarly well adapted to undertaking an original project of more than minimal scope. The average student, therefore, tackles a thesis with neither apathy nor trepidation; the superior student looks forward to it with considerable anticipation, as a culmination and final test of his professional training. In response to this attitude, the department faculty tends to set higher-than- average standards of performance on thesis research, and to offer other-than-routine problems for undergraduate investigation. Due to this highly critical attitude of student and staff alike toward thesis research, one finds that an excellent undergraduate thesis is one of the most reliable indications of a man's technical achievement and professional promise.

II. *Administration and Direction of the Undergraduate Thesis Program*

While initiative and originality are of prime importance in the student's pursuit of his thesis objective, each man is expected to adhere to a clearly defined procedure and schedule which experience has shown to encourage orderliness in work-a-day performance and a modicum of uniformity of final product. In recent years, the Department has established a Thesis Committee, under the direction of a faculty member, and staffed by instructors and teaching assistants, whose functions are to disseminate standardized procedural information to thesis men, to handle routine administrative work (registration, attendance, etc.), and in many other ways to relieve the faculty thesis supervisors of routine tasks in order that they may concentrate on the technical problems relating to the students' thesis projects. The Thesis Committee has been a boon to both students and faculty, and has done much to prevent the chaos that might be anticipated with as many as a hundred students carrying on thesis projects simultaneously.

The M.I.T. Chemical Engineering S.B. candidate is expected to spend 15 credit hours (about 15% of his time) on a thesis in his senior year. Except in unusual circumstances, this time is spread over the two semesters, three hours being spent during the first and the remainder during the second. The first semester's work is devoted to the selection of a subject, literature survey, preparation of a time-schedule for the second semester's research program, and the writing and submission of a preliminary report. During the second semester, therefore, the student carries out his proposed program and prepares his final report.

In most instances, the first-term senior selects his thesis subject from a very extensive list of topics prepared each semester by the individual faculty members and

bound in booklet form for distribution by the Thesis Committee. Before making a final decision, a student discusses those subjects in which he is interested with the appropriate faculty members. Normally, selection of a topic is completed within the first two weeks of the semester. In some cases, a student may have particular interest in a project which is not included in the above list; it is then the responsibility of the student to find a faculty member interested in that specific field, and to "sell" him on the importance and soundness of his proposed program.

Before embarking on his individual project, the student is expected to read and study carefully the Thesis Manual. This Manual is the product of many years of effort on the part of the Department Staff, and is based to a great extent on experiences in project organization and report-writing gained at the field stations of the School of Chemical Engineering Practice. The manual outlines the format and describes the functions of various types of technical reports; offers a guide to the use of the scientific and engineering literature; and presents the philosophy and objectives of both oral and written technical dissertations. It is the concerted opinion of the Staff that the Thesis Manual is an effective instrument for establishing high performance standards and a uniform basis for student-evaluation.

Throughout his entire senior year, the student is essentially on his own regarding the organization and method of attack of his thesis problem. He is, however, obliged to submit brief, periodic progress reports, to adhere to prescribed deadlines in submission of his preliminary and final reports, and to attend weekly thesis seminars. Procurement of standard items of laboratory equipment is handled on a strict sign-out basis, the student being fully and individually responsible for such equipment issued to him. For the construction of special apparatus, the student may avail himself of the excellent facilities of the Department shop. After obtaining approval of his equipment design (seldom without major revisions arising out of conferences with the shop instructor), he can proceed to build his apparatus under the watchful eyes of the permanent shop personnel. In many instances, education in the operation of machine tools and in establishing rapport with a skilled labor force are among the most valuable experiences of a student's undergraduate career.

The thesis student is encouraged to maintain personal contact with his faculty supervisor (particularly during the orientative phases of his program), although he is under no compulsion to do so. The supervisor normally does not exert directive pressure upon the student regarding his research plans, but acts in a purely advisory capacity. Conferences of this sort present an excellent opportunity for the supervisor to appraise the resourcefulness, initiative, and articulateness of the student, and play a large part in determining the final thesis grade.

III. *Written Work*

As has been mentioned above, each student prepares a preliminary report and weekly informal progress memos, as well as the final thesis. The preliminary report (submitted and graded at the end of the first semester) contains the results of library research presented as historical background of the project, a description of proposed procedure to be employed in the experimental program, and the intended methods of interpreting data and correlating results, a time-schedule, and bibliography. In most instances, the literature survey and introduction presented in the preliminary report can be incorporated into the final thesis with but minor revision.

Weekly progress memos consist merely of copies of laboratory data sheets, annotated bibliographies, etc., to which are attached single-page summaries of the week's accomplishments. These reports serve as a guide to the thesis supervisor regarding the student's ability to cope with research problems, and as well, serve as a measure of student effort.

The final written thesis is due (by In-

stitute regulation) one week before the end of the spring term. The time spent in preparing this report varies greatly, depending upon the student's ability to adhere to his proposed schedule, and upon the importance he attaches to clarity and continuity of written expression.

It is all too difficult to convince the average engineering undergraduate that evidence of care and thought in the preparation of reports plays a major role in the evaluation of technical competence. The thesis supervisor, therefore, has an obligation to drive this point home to his students; he must encourage them to begin writing early to self-criticize and revise, to seek the criticism of others, and revise again. This process, unpleasant as it may appear to the senior, inevitably pays dividends to the man who submits to it, in terms both of thesis-quality and ultimate professional achievement.

IV. *Oral Reports*

Weak as is the average undergraduate's capacity for handling the written work, his ability for articulate oral expression is even less fully developed. An important aspect of the undergraduate thesis program is participation in faculty-supervised seminars. Groups of ten to twelve students meet weekly during the latter half of each semester of the senior year with a faculty member; twice during the year each student is required to present to his colleagues a formal report on the progress of his thesis work. These talks are discussed and criticized by the members of the group, from the point of view of both technical soundness and quality of presentation. During the early phases of the seminar program, before a standard of reference has been established, responsibility for comment and criticism devolves mainly upon the faculty member present. It is not long, however, before the spirit and objectives of the seminar become evident to the group as a whole, and student participation becomes vigorous and highly constructive. The opportunity of addressing a group several times, and of giving and receiving frank and informal criticism, has proved to be remarkably effective in the rapid development of skill in oral communication.

V. *Grading and Evaluation of the Thesis*

Undergraduate theses are evaluated by two agencies. An impartial faculty member reviews and grades it in terms of apparent technical soundness and "salesmanship" in presentation. The thesis supervisor evaluates not only the report, but also its author, and his overall treatment of his project. The final grade is awarded on the basis of the concerted judgment of faculty reviewer and supervisor.

Failure to accomplish the ultimate goal of a thesis project is not a factor in student evaluation, unless such failure arises from negligence or ineptness on the part of the individual. As a matter of fact, relatively few undergraduates achieve their aims as set down in their preliminary project outlines. On the positive side, successful completion of a project is an indication, not necessarily of a high degree of scientific or engineering ability, but more often of soundness in judgment of the limitations of time and experience.

VI. *Some Non-Academic Justifications for the Undergraduate Thesis*

Beyond the essentially pedagogical objectives of the undergraduate thesis cited earlier in this discussion, there appear to be a number of consequences of thesis participation which have considerable impact upon the attitude of the student and the development of the post-collegiate career. The first of these is the matter of professional interest. The field of chemical engineering has become so expansive that it is impossible, in the brief span of four years, to give a student in the classroom more than the fundamentals and basic tools of the profession, and an opportunity to apply these fundamentals to more than a few industrial processes. The undergraduate thesis has thus become an instrument by which a student can examine in detail an important and unfamiliar phase of

chemical engineering; such an endeavor cannot fail to stimulate new interests, and to assist in selecting a job in an area of the field best suited to his talents and temperament. In interviewing seniors for positions, personnel men frequently use the thesis subject as a guide to the student's general interest in research or development work, and as an object for discussion during the interview. The enthusiasm and authoritativeness with which a man describes and comments upon his thesis problem is often accepted to be a good measure of his ability to handle new problems in the industrial frame.

Another important consequence of the thesis is the opportunity presented to the faculty supervisor to make a sound personal evaluation of the student. In writing a letter of recommendation regarding a student, or in replying to an inquiry about his capabilities, a staff member may justifiably be reluctant to express his frank opinion about a man with whom contact has been limited to the classroom. The thesis supervisor, however, develops a much clearer picture of the student's characteristics, and can comment intelligently, not only upon a man's intellectual capacities, but as well upon his industriousness, initiative, resourcefulness, and personality. If, indeed, an accurate appraisal of an individual contributes to the proper direction and molding of his professional career, then this aspect of the thesis program may be an important contribution to a student's ultimate success.

In summary, this discussion has attempted (1) to outline the M.I.T. Chemical Engineering Department's convictions regarding the educational value of the undergraduate thesis, (2) to describe the organization of the thesis program, and (3) to mention a few non-academic virtues of participation in formal thesis work at the undergraduate level. The conclusion is nearly inescapable that, for the development of mental and physical coordination, sound engineering judgment, and a power for coping with technical problems, the thesis far surpasses in value any classroom subject involving a comparable time expenditure. In Chemical Engineering, perhaps to a greater extent than in other scientific and engineering fields, the thesis must be considered an indispensable part of, and in a sense the consummation of, the undergraduate educational program.

In the News

Dr. Ralph A. Morgen, director of the Engineering and Industrial Experiment Station of the University of Florida, has been appointed to the staff of the Division of Mathematical, Physical and Engineering Sciences of the **National Science Foundation.** Dr. Morgen began his new duties on June 1, 1952. He is in charge of the Foundation's research support program in the engineering sciences.

Engineering Problems in the Utilization of Atomic Energy

By W. E. KELLEY

Manager, N. Y. Operations Office, Atomic Energy Commission

I am not a teacher of engineering—at least not in the formal sense—but for eight and a half years of the twenty years since my graduation as a civil engineer, my work has been in the utilization of atomic energy. By the normal limits of the "grandfather clause" that entitles me to speak on the subject of atomic engineering. Whereas we speak of using *nuclear* energy, our problems result from the behavior of the atom as an entity. We can't blame the nucleus, the protons, the neutrons, or any *part*—we are concerned with the whole. We are concerned with the radioactivity of a material, its physical and chemical characteristics, its possible toxicity, its use as a material of construction, its dust particle size.

This brings us to a fact that you as educators are facing: our problems in utilizing nuclear energy cut straight across the lines of conventional training. We use a specialist and we need him, but the big contributions come from men with solid foundation training who have understanding of related fields.

You may have noticed that in the make-up of the afternoon session the conventional headings of Electrical Engineering, Civil Engineering, Mechanical Engineering, Chemical Engineering are missing. We don't think that way in our business. We have a *problem*—it will be solved by teamwork and fundamental knowledge drawn from all fields. As a member of the parent group, a civil engineer, I see a possible return to the days when an engineer was trained in science, before "engineering" was broken into pieces for specialists. Naturally, we will need specialists, but perhaps that is for the graduate student. I would like to have a few men in my group who have been given four years training in science and its relation to engineering problems; they would be our project leaders of tomorrow.

The other day Dr. J. R. Oppenheimer, one of the world's great physicists, told your ASEE national steering committee on atomic energy that he would like to see a few oustanding young engineers spend one or two years on basic science problems. Here is proof of our judgment—a physicist wants engineers to be trained as scientists; I want scientists trained as engineers. What we both want is a man with two heads—one head trained as a scientist, and the other head trained as an engineer. The nearer we get to that ideal, the more the graduating product will contribute to atomic energy development.

Need Men with Ideas

You will hear this afternoon of some of the major engineering problems facing us in the development of atomic science, and you will see that although we talk of *problems* we are really talking of our need for *men with ideas!*

We now have 65,000 people working directly on the development of atomic science and the production of our materials and devices. Of those, 6445 are engineers used as engineers. We need more, as you can see by reading the want ads. Our contractors—duPont, Westinghouse, General Electric, Western Electric, Car-

bide and Carbon—all need men with ideas, the kinds of ideas that stem from good training in fundamentals.

In our business, the big contributions come from knowledge of the basic behavior of matter and materials, not from a superficial knowledge of fundamentals buried under a veneer of modern gadgetry. The engineer with a knowledge of items in the catalogue has a minor role in our work. He is supervised by an engineer who knows well the fundamentals that are now but briefly covered in the conventional engineers' undergraduate "college physics" course.

As civil and mechanical engineers we find that our detailed knowledge of the behavior of steel is interesting, but not very helpful if our new structure is to be built of beryllium or zirconium or some other exotic material. We become of more use than the catalogue engineer if we can plan intelligently a program of research and development that will expedite our training in the use of the new material in question.

A man trained in designing water pumps may or may not be of use to us in designing a pump for liquid sodium or elemental fluorine. If he really understands fundamentals, he can help us.

Problems That Face Us

Without encroaching on the afternoon's program, here are a few interesting problems that face us. They're *problems*—not problems in Mechanical, Electrical, or Chemical Engineering.

In our business there is a lot to learn about the design of processes in which the volume of off gases, waste liquids and sludges is kept to a minimum. Every cubic foot per minute of waste gas may require $5 initial investment for air cleaning equipment. The problem is compounded by the difficulty of maintaining the air cleaning equipment and the disposal of removed particulate matter, sometimes toxic and usually radioactive.

Batch processing of hazardous materials should be replaced wherever possible by continuous processing which inherently lends itself to hazard control. The process that *"can't"* be made continuous just hasn't had enough engineering.

We must learn more about the removal of trace amounts of radioactive materials from liquid effluents, because of health reasons and because of the value of our products.

Portable radiation detection instruments are now well into the production phase, but they are not sufficiently versatile; they are too expensive and too delicate. They need engineering!

The mechanics by which radioactive ground contamination is transported must be better understood, both as regards vertical and horizontal transport. The phenomena associated with the adsorption of trace materials on soils must be put into quantitative form.

A whole complex of engineering tasks will be encountered in the operation of nuclear energized aircraft. In outline it's simple; a nuclear unit will power an aircraft engine. But, let's consider the matter, excluding the purely nuclear part of the design of the power reactor. Considerable weight and volume of shielding will be required on the aircraft and in service buildings on the ground; remote handling equipment will be required; special equipment to move shield doors will be needed. The design of the aircraft itself will be a new aeronautical engineering problem when the weight-to-lift ratio is considered. The heat exchanger equipment will involve materials which are radioactive or which are exposed to radioactivity. All in all, here is a fertile field for imaginative engineering.

New Engineering Designs Required

In the industrial utilization of the radioactive properties of fission products new engineering designs will be required. New remote handling equipment and master-slave servo mechanisms will be needed. Television will be economically employed

Metallurgical problems are numerous. The operation of nuclear reactors at high temperature will require new metals and ceramics. Radiation in nuclear powered equipment can induce changes in materials. A material used in a reactor structure may either change into something else or have radically different characteristics. Electrical and thermal resistivities, elongations, corrosion properties, and structural stabilities are a few of the properties affected.

Monitoring and investigating the radiation associated with machines used in nuclear operations requires specialized electronic equipment to measure short time intervals (perhaps a hundredth of a millionth of a second) or to differentiate energy pulses initiated by different types of radiation. Equipment must be designed to do all these things and to operate with high sensitivity and with good stability.

The design and construction of machines such as the Brookhaven cosmotron requires, besides a high amperage pulsed voltage, which is accurately controlled, the fabrication of a doughnut-shaped metal vacuum chamber about 75 feet in diameter with apparently opposing requirements:

(*a*) thin walls, but with high mechanical strength, which disturb as little as possible the magnetic flux pattern.

(*b*) low operating pressure (5×10^{-6} mm. Hg or less) but as large a volume as possible in the horizontal and vertical magnet aperture.

In the less glamorous but highly important field of mining we need engineering help. Diamond drilling is used in finding most of our deposits. Drilling costs are rising, and we would like to know how to drill better holes, cheaper and faster—and where to drill them! !

As you can see from these few examples I have selected our problems cut across almost all engineering fields. Their solutions depend on getting well-trained engineers with good backgrounds of science to work on them.

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Statistics

I have some statistics on engineering employment on our program that may interest you. They bear out my thesis that there is no such thing as an atomic engineer. These figures are as of Jan. 1, 1951 and have since increased considerably. These men are engineers employed as engineers:

345	Civil
2	Agricultural
15	Highway
160	Safety
15	Marine Engineers and Naval Architects
50	Sanitary and Public Health
350	Structural and Architectural
355	Industrial and Administrative
1030	Chemical and Ceramics
1540	Electrical and Radio
1770	Mechanical
100	Heating and Ventilating
40	Refrigeration and Air Conditioning
105	Automotive
25	Aeronautical
105	Mining and Metallurgical
8	Petroleum and Geological
440	Engineers (Listing more than one major field)

bound in booklet form for distribution by the Thesis Committee. Before making a final decision, a student discusses those subjects in which he is interested with the appropriate faculty members. Normally, selection of a topic is completed within the first two weeks of the semester. In some cases, a student may have particular interest in a project which is not included in the above list; it is then the responsibility of the student to find a faculty member interested in that specific field, and to "sell" him on the importance and soundness of his proposed program.

Before embarking on his individual project, the student is expected to read and study carefully the Thesis Manual. This Manual is the product of many years of effort on the part of the Department Staff, and is based to a great extent on experiences in project organization and report-writing gained at the field stations of the School of Chemical Engineering Practice. The manual outlines the format and describes the functions of various types of technical reports; offers a guide to the use of the scientific and engineering literature; and presents the philosophy and objectives of both oral and written technical dissertations. It is the concerted opinion of the Staff that the Thesis Manual is an effective instrument for establishing high performance standards and a uniform basis for student-evaluation.

Throughout his entire senior year, the student is essentially on his own regarding the organization and method of attack of his thesis problem. He is, however, obliged to submit brief, periodic progress reports, to adhere to prescribed deadlines in submission of his preliminary and final reports, and to attend weekly thesis seminars. Procurement of standard items of laboratory equipment is handled on a strict sign-out basis, the student being fully and individually responsible for such equipment issued to him. For the construction of special apparatus, the student may avail himself of the excellent facilities of the Department shop. After obtaining approval of his equipment design (seldom without major revisions arising out of conferences with the shop instructor), he can proceed to build his apparatus under the watchful eyes of the permanent shop personnel. In many instances, education in the operation of machine tools and in establishing rapport with a skilled labor force are among the most valuable experiences of a student's undergraduate career.

The thesis student is encouraged to maintain personal contact with his faculty supervisor (particularly during the orientative phases of his program), although he is under no compulsion to do so. The supervisor normally does not exert directive pressure upon the student regarding his research plans, but acts in a purely advisory capacity. Conferences of this sort present an excellent opportunity for the supervisor to appraise the resourcefulness, initiative, and articulateness of the student, and play a large part in determining the final thesis grade.

III. *Written Work*

As has been mentioned above, each student prepares a preliminary report and weekly informal progress memos, as well as the final thesis. The preliminary report (submitted and graded at the end of the first semester) contains the results of library research presented as historical background of the project, a description of proposed procedure to be employed in the experimental program, and the intended methods of interpreting data and correlating results, a time-schedule, and bibliography. In most instances, the literature survey and introduction presented in the preliminary report can be incorporated into the final thesis with but minor revision.

Weekly progress memos consist merely of copies of laboratory data sheets, annotated bibliographies, etc., to which are attached single-page summaries of the week's accomplishments. These reports serve as a guide to the thesis supervisor regarding the student's ability to cope with research problems, and as well, serve as a measure of student effort.

The final written thesis is due (by In-

stitute regulation) one week before the end of the spring term. The time spent in preparing this report varies greatly, depending upon the student's ability to adhere to his proposed schedule, and upon the importance he attaches to clarity and continuity of written expression.

It is all too difficult to convince the average engineering undergraduate that evidence of care and thought in the preparation of reports plays a major role in the evaluation of technical competence. The thesis supervisor, therefore, has an obligation to drive this point home to his students; he must encourage them to begin writing early to self-criticize and revise, to seek the criticism of others, and revise again. This process, unpleasant as it may appear to the senior, inevitably pays dividends to the man who submits to it, in terms both of thesis-quality and ultimate professional achievement.

IV. *Oral Reports*

Weak as is the average undergraduate's capacity for handling the written work, his ability for articulate oral expression is even less fully developed. An important aspect of the undergraduate thesis program is participation in faculty-supervised seminars. Groups of ten to twelve students meet weekly during the latter half of each semester of the senior year with a faculty member; twice during the year each student is required to present to his colleagues a formal report on the progress of his thesis work. These talks are discussed and criticized by the members of the group, from the point of view of both technical soundness and quality of presentation. During the early phases of the seminar program, before a standard of reference has been established, responsibility for comment and criticism devolves mainly upon the faculty member present. It is not long, however, before the spirit and objectives of the seminar become evident to the group as a whole, and student participation becomes vigorous and highly constructive. The opportunity of addressing a group several times, and of giving and receiving frank and informal criticism, has proved to be remarkably effective in the rapid development of skill in oral communication.

V. *Grading and Evaluation of the Thesis*

Undergraduate theses are evaluated by two agencies. An impartial faculty member reviews and grades it in terms of apparent technical soundness and "salesmanship" in presentation. The thesis supervisor evaluates not only the report, but also its author, and his overall treatment of his project. The final grade is awarded on the basis of the concerted judgment of faculty reviewer and supervisor.

Failure to accomplish the ultimate goal of a thesis project is not a factor in student evaluation, unless such failure arises from negligence or ineptness on the part of the individual. As a matter of fact, relatively few undergraduates achieve their aims as set down in their preliminary project outlines. On the positive side, successful completion of a project is an indication, not necessarily of a high degree of scientific or engineering ability, but more often of soundness in judgment of the limitations of time and experience.

VI. *Some Non-Academic Justifications for the Undergraduate Thesis*

Beyond the essentially pedagogical objectives of the undergraduate thesis cited earlier in this discussion, there appear to be a number of consequences of thesis participation which have considerable impact upon the attitude of the student and the development of the post-collegiate career. The first of these is the matter of professional interest. The field of chemical engineering has become so expansive that it is impossible, in the brief span of four years, to give a student in the classroom more than the fundamentals and basic tools of the profession, and an opportunity to apply these fundamentals to more than a few industrial processes. The undergraduate thesis has thus become an instrument by which a student can examine in detail an important and unfamiliar phase of

chemical engineering; such an endeavor cannot fail to stimulate new interests, and to assist in selecting a job in an area of the field best suited to his talents and temperament. In interviewing seniors for positions, personnel men frequently use the thesis subject as a guide to the student's general interest in research or development work, and as an object for discussion during the interview. The enthusiasm and authoritativeness with which a man describes and comments upon his thesis problem is often accepted to be a good measure of his ability to handle new problems in the industrial frame.

Another important consequence of the thesis is the opportunity presented to the faculty supervisor to make a sound personal evaluation of the student. In writing a letter of recommendation regarding a student, or in replying to an inquiry about his capabilities, a staff member may justifiably be reluctant to express his frank opinion about a man with whom contact has been limited to the classroom. The thesis supervisor, however, develops a much clearer picture of the student's characteristics, and can comment intelligently, not only upon a man's intellectual capacities, but as well upon his industriousness, initiative, resourcefulness, and personality. If, indeed, an accurate appraisal of an individual contributes to the proper direction and molding of his professional career, then this aspect of the thesis program may be an important contribution to a student's ultimate success.

In summary, this discussion has attempted (1) to outline the M.I.T. Chemical Engineering Department's convictions regarding the educational value of the undergraduate thesis, (2) to describe the organization of the thesis program, and (3) to mention a few non-academic virtues of participation in formal thesis work at the undergraduate level. The conclusion is nearly inescapable that, for the development of mental and physical coordination, sound engineering judgment, and a power for coping with technical problems, the thesis far surpasses in value any classroom subject involving a comparable time expenditure. In Chemical Engineering, perhaps to a greater extent than in other scientific and engineering fields, the thesis must be considered an indispensable part of, and in a sense the consummation of, the undergraduate educational program.

In the News

Dr. Ralph A. Morgen, director of the Engineering and Industrial Experiment Station of the University of Florida, has been appointed to the staff of the Division of Mathematical, Physical and Engineering Sciences of the **National Science Foundation.** Dr. Morgen began his new duties on June 1, 1952. He is in charge of the Foundation's research support program in the engineering sciences.

Engineering Problems in the Utilization of Atomic Energy

By W. E. KELLEY

Manager, N. Y. Operations Office, Atomic Energy Commission

I am not a teacher of engineering—at least not in the formal sense—but for eight and a half years of the twenty years since my graduation as a civil engineer, my work has been in the utilization of atomic energy. By the normal limits of the "grandfather clause" that entitles me to speak on the subject of atomic engineering. Whereas we speak of using *nuclear* energy, our problems result from the behavior of the atom as an entity. We can't blame the nucleus, the protons, the neutrons, or any *part*—we are concerned with the whole. We are concerned with the radioactivity of a material, its physical and chemical characteristics, its possible toxicity, its use as a material of construction, its dust particle size.

This brings us to a fact that you as educators are facing: our problems in utilizing nuclear energy cut straight across the lines of conventional training. We use a specialist and we need him, but the big contributions come from men with solid foundation training who have understanding of related fields.

You may have noticed that in the makeup of the afternoon session the conventional headings of Electrical Engineering, Civil Engineering, Mechanical Engineering, Chemical Engineering are missing. We don't think that way in our business. We have a *problem*—it will be solved by teamwork and fundamental knowledge drawn from all fields. As a member of the parent group, a civil engineer, I see a possible return to the days when an engineer was trained in science, before "engineering" was broken into pieces for specialists. Naturally, we will need specialists, but perhaps that is for the graduate student. I would like to have a few men in my group who have been given four years training in science and its relation to engineering problems; they would be our project leaders of tomorrow.

The other day Dr. J. R. Oppenheimer, one of the world's great physicists, told your ASEE national steering committee on atomic energy that he would like to see a few oustanding young engineers spend one or two years on basic science problems. Here is proof of our judgment—a physicist wants engineers to be trained as scientists; I want scientists trained as engineers. What we both want is a man with two heads—one head trained as a scientist, and the other head trained as an engineer. The nearer we get to that ideal, the more the graduating product will contribute to atomic energy development.

Need Men with Ideas

You will hear this afternoon of some of the major engineering problems facing us in the development of atomic science, and you will see that although we talk of *problems* we are really talking of our need for *men with ideas!*

We now have 65,000 people working directly on the development of atomic science and the production of our materials and devices. Of those, 6445 are engineers used as engineers. We need more, as you can see by reading the want ads. Our contractors—duPont, Westinghouse, General Electric, Western Electric, Car-

bide and Carbon—all need men with ideas, the kinds of ideas that stem from good training in fundamentals.

In our business, the big contributions come from knowledge of the basic behavior of matter and materials, not from a superficial knowledge of fundamentals buried under a veneer of modern gadgetry. The engineer with a knowledge of items in the catalogue has a minor role in our work. He is supervised by an engineer who knows well the fundamentals that are now but briefly covered in the conventional engineers' undergraduate "college physics" course.

As civil and mechanical engineers we find that our detailed knowledge of the behavior of steel is interesting, but not very helpful if our new structure is to be built of beryllium or zirconium or some other exotic material. We become of more use than the catalogue engineer if we can plan intelligently a program of research and development that will expedite our training in the use of the new material in question.

A man trained in designing water pumps may or may not be of use to us in designing a pump for liquid sodium or elemental fluorine. If he really understands fundamentals, he can help us.

Problems That Face Us

Without encroaching on the afternoon's program, here are a few interesting problems that face us. They're *problems*—not problems in Mechanical, Electrical, or Chemical Engineering.

In our business there is a lot to learn about the design of processes in which the volume of off gases, waste liquids and sludges is kept to a minimum. Every cubic foot per minute of waste gas may require $5 initial investment for air cleaning equipment. The problem is compounded by the difficulty of maintaining the air cleaning equipment and the disposal of removed particulate matter, sometimes toxic and usually radioactive.

Batch processing of hazardous materials should be replaced wherever possible by continuous processing which inherently lends itself to hazard control. The process that *"can't"* be made continuous just hasn't had enough engineering.

We must learn more about the removal of trace amounts of radioactive materials from liquid effluents, because of health reasons and because of the value of our products.

Portable radiation detection instruments are now well into the production phase, but they are not sufficiently versatile; they are too expensive and too delicate. They need engineering!

The mechanics by which radioactive ground contamination is transported must be better understood, both as regards vertical and horizontal transport. The phenomena associated with the adsorption of trace materials on soils must be put into quantitative form.

A whole complex of engineering tasks will be encountered in the operation of nuclear energized aircraft. In outline it's simple; a nuclear unit will power an aircraft engine. But, let's consider the matter, excluding the purely nuclear part of the design of the power reactor. Considerable weight and volume of shielding will be required on the aircraft and in service buildings on the ground; remote handling equipment will be required; special equipment to move shield doors will be needed. The design of the aircraft itself will be a new aeronautical engineering problem when the weight-to-lift ratio is considered. The heat exchanger equipment will involve materials which are radioactive or which are exposed to radioactivity. All in all, here is a fertile field for imaginative engineering.

New Engineering Designs Required

In the industrial utilization of the radioactive properties of fission products new engineering designs will be required. New remote handling equipment and master-slave servo mechanisms will be needed. Television will be economically employed.

Metallurgical problems are numerous. The operation of nuclear reactors at high temperature will require new metals and ceramics. Radiation in nuclear powered equipment can induce changes in materials. A material used in a reactor structure may either change into something else or have radically different characteristics. Electrical and thermal resistivities, elongations, corrosion properties, and structural stabilities are a few of the properties affected.

Monitoring and investigating the radiation associated with machines used in nuclear operations requires specialized electronic equipment to measure short time intervals (perhaps a hundredth of a millionth of a second) or to differentiate energy pulses initiated by different types of radiation. Equipment must be designed to do all these things and to operate with high sensitivity and with good stability.

The design and construction of machines such as the Brookhaven cosmotron requires, besides a high amperage pulsed voltage, which is accurately controlled, the fabrication of a doughnut-shaped metal vacuum chamber about 75 feet in diameter with apparently opposing requirements:

(*a*) thin walls, but with high mechanical strength, which disturb as little as possible the magnetic flux pattern.

(*b*) low operating pressure (5×10^{-6} mm. Hg or less) but as large a volume as possible in the horizontal and vertical magnet aperture.

In the less glamorous but highly important field of mining we need engineering help. Diamond drilling is used in finding most of our deposits. Drilling costs are rising, and we would like to know how to drill better holes, cheaper and faster—and where to drill them!!

As you can see from these few examples I have selected our problems cut across almost all engineering fields. Their solutions depend on getting well-trained engineers with good backgrounds of science to work on them.

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8	Petroleum and Geological
440	Engineers (Listing more than one major field)

This should dispel the idea that there is but small place in atomic energy work for the man without training in nuclear science. Today, the converse is true. Opportunities exist in the normal specialties —with top positions open to the man who can straddle more than one field.

It is you—the engineering educators—who must see to it that graduates are equipped to exploit knowledge of the atom just as engineers before them have beaten into useful shape the other great discoveries of science.

College Notes

The Department of Meteorology of **New York University's** College of Engineering has been redesignated the Department of Meteorology and Oceanography. Formal curricula leading to the master's and doctor's degrees became effective at the opening of the academic year in September.

Laurens Troost, whose achievements as a naval architect in The Netherlands have won him international recognition, will become professor and head of the Department of Naval Architecture and Marine Engineering at the **Massachusetts Institute of Technology** this autumn.

Jesse W. Mason, Dean of Engineering at the **Georgia Institute of Technology,** was granted a year's leave-of-absence effective September 1, 1952, in order to participate in the Educator in Industry Program of the E. I. du Pont de Nemours & Co., Wilmington, Del. Dr. Mason was one of the first educators to be selected by E. I. du Pont de Nemours & Co. for this new program of cooperative exchange of educators with that industry, and was chosen because of his outstanding reputation in the field of chemical engineering.

Dean William C. White, Director of the Day Colleges at **Northeastern University,** has been named Vice President of the University. He will assume his new duties on January 1, 1953. Starting at Northeastern in 1926 as an instructor, Dr. White rose in the academic ranks serving as assistant professor, associate professor, Dean of Engineering, and Director of the Day Colleges. He is at present Vice President in charge of instructional division activities of the American Society for Engineering Education.

Elmer R. Queer, professor of engineering research and assistant director of the Engineering Experiment Station at the **Pennsylvania State College,** has been appointed director of the department of engineering research and Paul Ebaugh, professor of engineering research, has been named assistant director of the department. In announcing the appointments, Dr. Milton S. Eisenhower, president of the College, explained that the Trustees had also approved the changing of the name of the Engineering Experiment Station to the department of engineering research. The new name, Dr. Eric A. Walker, dean of the School of Engineering and Vice President, A.S.E.E., explains, more clearly conveys the research and development functions of the department while the term, "Experiment Station," when adopted, indicated a test station. The department today does little testing.

Aeronautical Engineers, 1952 Supply and Demand

By K. D. WOOD

Professor and Head, Aeronautical Engineering Department, University of Colorado

Summary

The following article presents what is believed to be an accurate estimate, based on current questionnaires, of the supply of aeronautical engineering graduates in 1952 and the corresponding demand by the aircraft industry and supporting civilian laboratories.

In brief, the study shows that the demand exceeds the supply by a factor of about three. It also shows that the shortage will get worse for at least three years.

It is suggested that a scholarship program sponsored by the Air Force, Navy, and/or the Aircraft Industry is essential to the national defense if engineering education is to be kept on a voluntary basis.

Procedure for Survey of Schools

The simple questionnaire shown in Fig. 1 was sent to fifty schools giving degrees in aeronautical engineering (or aeronautical options in mechanical engineering) in

AERONAUTICAL ENGINEERING ENROLLMENT SURVEY
FEBRUARY 1952

			Estimated No. in R.O.T.C.
Graduates in calendar year 1951:	M.S.....	B.S.....	.....
Expected graduates in calendar year 1952:	M.S.....	B.S.....	.....
Possible graduates in calendar year 1953 (Junior students now enrolled):.....			.....
Possible graduates in calendar year 1954 (Soph. students now enrolled):			.....
Possible graduates in calendar year 1955 (Fresh. students now enrolled):.....			.....

Signed,

What R.O.T.C.
Army.....
A.F.....
Navy.....

( ) Check here if you wish identity of institution not revealed except in statistical summary.

For the Dept. Head or Chairman, Aeronautical Engineering or Prof. in Charge of Aeronautics.

..... (Institution)

..... (Address)

FIG. 1. Questionnaire sent out.

TABLE 1

AERONAUTICAL ENGINEERING ENROLLMENT SURVEY DATA, SPRING 1952

Code No.	Basis	Org.	Students reported, class of					Non-ROTC students, class of			
			'51	'52	'53	'54	'55	'52	'53	'54	'55
1	52	D	8	5	17	26	39	0	19	6e	9e
2	1	D	17	12	13	13	15e	10e	10e	6e	7e
3	52	M	27	28	21	30	28	25e	20e	13e	15e
4	0	M	15	12e	11e	15e	17e	10e	7e	7e	8e
5	52	D	24	19	18	13	35	15	12	7	18
6	52	D	13	10	5	5	6	10	5	4	6
7	52	D	12	12	7	11e	12e	6	3	5e	6e
8	52	D	50	35	25	33	68	13e	12e	8e	0e
9	52	D	41	30	26	33	49	15	13	0	0
10	52	D	18	12	10	15	20	12	10	15	10e
11	52	D	82	69	45	50	50	49	25	25	25
12	1	D	14	15	20	33	36e	14e	16e	17e	18e
13	52	D	4	10	17	18	33	8	11	9e	17e
14	52	M	0	3	4	5	5	2	2	3	3
15	52	D	25	8	5	12	12	6	2	3	2
16	52	D	12	14	19	20	83	13	14	7	21
17	52	D	50	37	38	24	0	25	17	0	0
18	52	M	14	12	10e	11e	12e	12	10e	8e	6e
19	52	D	70	25	23	18	25	30	20	9	12
20	52	D	20	18	10	17	4	16	9	13	2e
21	52	D	8	2	8	16	12	2	6	11	7
22	52	D	8	6	6	7e	8e	6	6	3e	4e
23	52	D	24	15	19	23	34	13	14e	12e	17e
24	52	D	3	6	2	13	15e	2	1	1	7e
25	52	M	14	6	9	12	27	5	4	5	7
26	52	M	3	3	1	2	8	0	0	0	0
27	52	D	10	10	10	12	14	8	9	10	9
28	52	M	4	4	7	10	26	4	5	10	26
29	52	D	44	35	15	10	17	35	15	10	17
30	52	D	48	30	30	30	33e	27e	24e	15e	17e
31	1	D	12	6	6e	12e	14e	5e	5e	6e	7e
32	52	D	68	55	48	38	43e	51	48	2	21e
33	1	M	15	15	15e	17e	20e	13e	10e	8e	10e
34	52	D	22	18	17	12	10	14	14	9	5e
35	52	D	39	27	15	22	23	23	9	14	15
36	52	D	18	18	12	16	24	17e	10e	8e	12e
37	52	D	9	6	7	8	22	6	5	5	14
38	52	M	10	8	7	7	8e	5	2	3e	4e
39	1	M	9	8e	7e	9e	9e	6e	5e	4e	4e
40	52	M	13	22	13	10	22	19	10	5	6
41	0	D	36e	32e	30e	36e	40e	28e	24e	18e	20e
42	52	D	12	19	31	23	30	10e	16e	12e	15e
43	1	D	25	30	48	58	64e	0	0	0	0
44	52	M	3	1	5	10	10	1	0	2	5e
45	52	D	8	7	8	15	21	0	0	0	10e
46	1	M	7	10	8e	9e	10e	8e	6e	4e	5e
47	1	D	27	18	20	25	28e	16e	16e	12e	14e
48	52	M	4	8	4	8	10	8	1	4	2
49	52	D	27	18	16	19	50	13	10	12	25e
50	1	D	8	15	7	8e	10e	12e	5e	4e	5e
Totals			1052	850	765	899	1211	626	492	369	459
Probable Av. Grads			21	17	14	14	18				

Abbreviations—Basis: 52, 1, 0—Questionnaire returned, spring of 1952, 51, 50 respectively. Org.: D = separate dept., M = option in ME. Data: e = estimated.

February of 1952. The list of schools surveyed is intended to be comprehensive, in that it includes ALL schools in the U.S. accredited in *any* branch of engineering which give such instruction whether or not they are accredited in aeronautical engineering. The totals of the list, therefore, represent nearly the total supply of aeronautical engineering manpower available in the United States (some technical institute trainees are also available).

Replies were received this spring from 78% of the schools solicited, the remaining figures having been estimated from a similar survey last year. A summary of the results is presented in Table 1 and the school identification, where authorized by the person replying, is given in Table 2. A summary of the results was sent to each participating school about March 11, 1952.

Procedure for Survey of Demand

Demand was estimated by interviewing the company interviewers who visited the University of Colorado in 1952 prior to April 15, and multiplying the stated employment goal of each company by the ratio of the published (1) total industrial back-log to the back-log of the companies interviewed. For example, the employment goal of six large manufacturers which hold 47% of the national back-log is 2300 additions to their engineering employment. If these companies are typical, the national goal of the aircraft manufacturers for 1952 is 5000. Preliminary figures sent out March 11 to the participating schools, and based on a smaller sample, yielded an estimate of 6000 for 1952 and a possible relaxation of demand if these goals were obtained. The figure 5000 is based on a larger sample. Government Laboratory figures are more difficult to estimate, but using figures given in Ref. 1, p. 49 on total employment of engineers in government laboratories and assuming that their ratio of demand to employment is at least as great as in the industry (it is believed to be greater), the demand in government laboratories is estimated at 2000. It is thus evident that the aircraft industry and supporting government laboratories would hire 7000 engineers this year if they could. Of these 7000, about 27% (a figure supplied by Prof. F. S. Eastman, University of Washington) or 2000 would be B.S. Aero. E. graduates *if available.*

Discussion of Results

Fig. 2 is a plot showing the number of students in each class at each of the schools surveyed in the spring of 1952 with median and average figures given for the total number of students now enrolled. The probable average civilian graduating class for the next 3 years, based on a conservative attrition rate of 10% per year, is also shown. This picture represents a continuation of a downward trend in engineering graduates which has existed since 1950. One explanation is the small birth rate 20 years before, but this is a relatively minor factor. Another is the running out of the "G. I. Bill" for college

TABLE 2

SCHOOL IDENTIFICATION, WHERE AUTHORIZED

1. Ala. Poly., Auburn	15. U. of Kansas, Lawrence	38. Oregon State Col.
2. U. of Ala., University	16. U. of Wichita	39. Drexel Inst., Phila.
3. U. of Calif., Berkeley	17. Mass. Inst. Tech.	41. Penn. State Col.
4. U. of South. Calif., L.A.	19. U. of Michigan	42. U. of Texas, Austin
5. U. of Colo., Boulder	25. N. C. State, Raleigh	43. Texas A. & M.
8. Georgia Tech., Atlanta	31. Syracuse U.	45. Utah A. & M., Logan
10. Ind. Tech., Ft. Wayne	33. Case Inst., Cleveland	46. U. of Utah, Salt Lake
12. Notre Dame	34. U. of Cincinnati	47. Va. Poly., Blacksburg
14. U..of Iowa, Iowa City	36. U. of Okla., Norman	49. U. of Wash., Seattle
	37. U. of Tulsa	50. U. of W. Va.

students. It is also possible that the large number of boys who have enlisted in the armed services recently may be partly in anticipation of a post-Korea "G.I. Bill" as well as avoidance of the draft.

A combined picture of supply and demand is shown in Fig. 3. The heaviest line labeled "present students" is the total from all schools replying and is consistent with the Aeronautical Engineering enrollment figures in Ref. 2. The number of these who will probably graduate is also estimated and labeled "estimated graduate 10% attrition." The figure of 10% per year is conservative for normal times, the average of engineering schools over the United States being somewhat larger, but the lower figure is believed to be justified because of the unusual pressure on the students due to draft boards and other factors.

The number of present students without R.O.T.C. commitments, based on the questionnaires returned, is also shown in Fig. 3; and if the same percentage of attrition is applied to the present students without R.O.T.C. commitments as to all students, the lowest line gives the estimated civilian graduates. The line in Fig. 3 labeled "probable supply" takes account of the possibility that 80% of the officers called to active duty will be released after two years service, in accordance with their present agreements. But it is, of course, within the authority of the military services to make such service either longer or shorter, depending upon the international situation. In any case, it is evident that not more than an average of 600 unobligated aeronautical engineering graduates per year can be obtained from present schools in the United States for the coming three years, or a total of less than 2000 aeronautical engineers. The solution is not to transfer students from other branches to aeronautical engineering since the other branches are in similar short supply.

However, reference (2) shows that for *every* aeronautical engineering student registered in E.C.P.D. accredited schools, there are about 9 M.E.'s, 8 E.E.'s, and 7 C.E.'s (a total of 37 in all other branches of engineering). If or when industrial conditions become such that substantial "conversion" of other engineering graduates to aeronautical work becomes possible, the shortage in the aeronautical field may be fairly quickly eliminated.

Concluding Remarks

The question is raised as to whether the large sums appropriated for airplane development and construction can have meaning in the light of the trend in "free enterprise" education shown in Fig. 3. Can the money be spent if there are insufficient engineers to pay it to, for the purposes for which it was appropriated?

May not the answer to the shortage of engineering college students be a scholarship program, such as has been proposed by the National Science Foundation, but limited to aircraft and other critical defense industries?

May it not be true now, as it was in World War II, that if the military services need greatly increased numbers of college trained officers, they will have to send them to college; and if they want improved airplanes, tanks, and other complicated weapons, will they have to provide college training for the necessary civilian engineers as well as the military and naval officers? Funds already appropriated may be sufficient for such a training program if they can not be spent directly for engineering development work on account of the shortage of engineers.

References

(1) *Aviation Week*, Feb. 25, 1952, p. 33.

(2) Story, Robert C., and Armsby, Henry H. "Engineering Enrollments and Degrees 1951." *The Journal of Engineering Education*, Feb. 1952. Summary table on p. 5.

An Estimate of the Success of the Five-Year Mineral Engineering Programs*

By WILLIAM B. PLANK

Head of Department of Mining and Metallurgical Engineering, Lafayette College

In addition to the diversity in the titles of curricula in the United States Schools of Mineral Engineering, there has developed recently in a few schools a lengthening of the undergraduate program from the norm of four years instruction to five or more years for the first or bachelor degree (1). In the institutions involved the lengthened program has been applied to all engineering branches.

History of the Five-Year Programs

For a number of years, there have been cooperative undergraduate engineering courses of longer than four years in a few engineering schools. Perhaps the most noted is at the University of Cincinnati which has the longest experience in this type of program, begun in 1906 under Dean Herman Schneider. The SPEE Board of Investigation and Coordination, in its 1923–29 report, lists eighteen such programs.

Since 1903 at Harvard University, the first degree in mining or metallurgy has been obtainable only after a bachelor's degree in the Arts College, and this same program was adopted at Stanford University in 1925.

At Columbia University, three years of study in the arts college are required before entering the School of Mines and Engineering where two more years are required for the first engineering degree.

T. T. Read said of the results of these programs:

"The Dean of Engineering at Harvard later characterized its policy of dropping the four-year engineering curricula as a 'costly mistake.' The effect on mineral industry registration does not seem to have been as immediately serious at Stanford as at Columbia, but eventually it was. At Columbia, the effects were so severe on the whole engineering school that requirements were progressively so modified that an adequately prepared student can now obtain a B.S. degree in an engineering field in four years (the degree is Bachelor of Science) and the engineer degree in five. Even with this liberalization the mineral industry undergraduate registration has never recovered from the blow dealt it, and the major interest of the mining and metallurgical department has become graduate work" (2).

Ohio State University instituted its five-year engineering programs in 1945, at the conclusion of which it is possible for some students to attain the Master of Science in addition to the Bachelor engineering degree. The 1951 class was the first to graduate under these programs.

The University of Minnesota began its five-year program in 1946 which leads only to the Bachelor engineering degree.

Cornell University first applied its five-year program to Engineering Physics in 1946 and extended it to the other engineering branches, including Metallurgical Engineering, about 1948. The degree attained is Bachelor of Metallurgical Engineering.

* An address at American Society for Engineering Education, Mineral Engineering Division, East Lansing, Michigan, June 26, 1951.

The Three-Two Plan

Another type of lengthened program for engineering education is that provided by an arrangement between engineering schools and certain liberal arts colleges known as the three-two plan. By this plan the student may obtain both an A.B. and a Bachelor of engineering degree after three years work at the arts college and two years at the engineering school.

This plan has been in operation for several years at Carnegie Tech., M. I. T., and other institutions and has just recently been instituted at Columbia University and Lafayette College. The plan is not the same, however, as the ones we are discussing here because there is involved the registration in two different colleges or universities which may be considered similar to post-graduate work.

This plan has much to be said in its favor and it should be the means of turning many good men into engineering who would otherwise go into other professions.

Objectives of Five-Year Programs

I am inclined to believe that the motives and objectives for these longer programs have been mixed, but the one most often put forward is the desire on the part of the schools involved to broaden and enrich the engineer's undergraduate education with so-called cultural subjects in order to make him a better citizen and, in a fuller sense, to enable him to become a better engineer.

The SPEE Committee on "Aims and Scope of Engineering Curricula," of which Dean H. P. Hammond was chairman, in its report in the *Journal of Engineering Education* for March 1940, outlined its recommendations on this matter as follows:

"First—broadening of the base of engineering education, now in process, should be continued. Its roots should extend more deeply into the social sciences and humanities as well as into the physical sciences in order to sustain a rounded educational growth which will continue into professional life. Two stems are thus implied in the undergraduate curriculum which we have designated as (1) the scientific-technological and (2) the humanistic-social. Each of these should be organized in an articulated sequence of subject matter and disciplines designed to lead to definite educational objectives."

The Committee recommends, however, that the way to achieve these objectives is not to lengthen the program but rather to "require greater efficiency in the use of the student's time to be gained by pruning to the essentials of a sound educational program." It concludes that "the present flexible arrangement of four-year undergraduate curricula followed by post-graduate work will better meet the needs served by engineering education than will longer undergraduate curricula of uniformly prescribed duration."

William E. Wickenden in his *Second Mile,* that superb dissertation on the philosophy of the profession of engineering, made the following comments on the question of required longer training for engineers:

"The proposal to compel all engineering students to remain six years or more in college in order to complete combined courses in liberal arts and in engineering is attractive in theory but unworkable in practice. Some young men should do so, but the majority will not. Those who do are likely to find that the advantage gained comes quite as much, or even more, from sharing the life and spirit of two divisions of education with differing ideals and traditions, as from a more extended range of studies. The advantage of breadth, so gained, must be weighed against the depth which might result from devoting the same length of time to a combination of undergraduate and post-graduate training. No combined program in arts and engineering requiring more than four years can be made compulsory in the face of the demands of industry, the attractive terms offered to four-year graduates, and the wide range of engineering responsibility; nor is it likely to succeed so long as the typical student engineer, as graduation approaches, shows so unmistakably that he is fed up for a time with formal teaching and study and craves action and experience.

"Much has happened in late years to strengthen the belief that possibilities in the mile of voluntary advancement are more hopeful than any lengthened mile of compulsory discipline. Growth in post-graduate enrollments in engineering colleges in the pre-war years was especially impressive, with the ratio of master's to bachelor's degree rising above one to ten and that of doctorates nearing one to a hundred. What was particularly noteworthy was that so many of these advanced students were pursuing interests and needs which they had discovered for themselves in their early professional experience, rather than a further discipline—however ideal—which others had imposed upon them" (3).

Dugald C. Jackson, who reviewed the trends in engineering education in 1939, concurs with Dr. Wickenden in this matter as follows:

"One solution which has been proposed, that of a general lengthening of the under graduate period by one year or more, is not adequate because the most competent and ambitious students wish to pursue graduate work and many who are not restrained by personal obligations succeed in doing so. This trend toward graduate study has been encouraged by the engineering schools and is worthy of such encouragement. Such young men as suitably follow the trend will, by their individual efforts, fill any voids of humanistic studies which are without applied content but which come into the category of desirable general knowledge. Curricula of extended undergraduate length would stop those students from securing the (for them) great advantages to be derived from graduate work; while those who can profit particularly by a lengthened undergraduate curriculum can now find a number of institutions meeting their situation. Other students may graduate in arts, with a suitable background of science, and thereafter complete a sound undergraduate engineering course in two additional years; but this procedure now seems to command less favor than it did a few years ago" (4).

Let us now examine the results of some of these programs and see how they have affected enrollment and the "Sales Value" of the graduates from them.

Effect on Enrollment

First, it is found from my detailed enrollment data that the undergraduate enrollment in mineral engineering courses has fallen off in three of the five-year schools during the past two years, at a rate more than double the reduction in the total mineral engineering enrollment in the United States. At one institution, where the longer program has been in effect for more than thirty-five years, the undergraduate enrollment in mining and metallurgy in 1950–51 was just half what it was two years ago. During this same period, the undergraduate mineral engineering enrollment in the whole Country fell off twenty per cent.

This means that although the total group of undergraduates during these two years has become smaller, largely because of the graduation of veterans, the students in these three schools are turning to the standard four-year programs rather than to the longer programs.

Market Value of the Graduates

An even more important measure of the five-year curricula is the estimate placed by employers on the product of the longer programs compared with that of the four-year curricula.

One employer of engineers, himself a graduate from a four-year course at one of the institutions now following the five-year plan, has this to say about the plan:

"There is an impression in the minds of some people that the students have been given this extra year for a purpose, and that they should be worth more than boys from schools with the four-year course. There is nothing tangible that we can see that would justify this conclusion. We are offering the same pay to all men with bachelor degrees from all schools.

"Furthermore, these boys do not seem to be able to convince even themselves that they have obtained 25 per cent more value in their five-year course than if they had taken the usual four-year course. Unfortunately, it may be several years before they can evaluate the benefit, if any, from the extra year.

"Even graduate courses in engineering are of less value to a man than if he were to enter Industry immediately, after a four-year B.S., and take a training course in the industry.

"Just at this time, when we are feeling the effects of the misinformation from the Department of Labor over a year ago in regard to the oversupply of engineers, together with the demands of Selective Service, Industry finds itself in a very critical condition in so far as available manpower is concerned.

"Industry offers training courses that are oftentimes much more thorough and worthwhile in the early years of the graduate's employment than is the extra school work given in the fields where a man's future life is largely that of an individual in his chosen profession. Engineers obtain much better training in most companies by direct contact and mutual contribution in their development for the work ahead, than can possibly be given in the academic influence of the five-year course.

"As to who is the better judge of problems of this kind—I have found that any manufacturer is compelled to accept the judgment of the purchaser and user of his products rather than depend upon his sales and production departments for their opinions. I therefore think that those who employ the product of our engineering schools are more interested and better able to judge."

Conclusions

1. In considering the present and future scarcity of engineers as well as the projected annual national demands for 30,000, along with the smaller future enrollments that will result from the changes in population ages, the indications seem to be that the longer educational programs will become even less popular in the immediate future than they now are.

2. An examination of the curricula in three of the schools involved reveals that, although the humanistic social subjects are broadened, much more time is devoted to technological subjects than in most four-year programs.

3. The consensus of the ASEE authorities quoted in this paper clearly indicates that four years would be long enough for a great majority of engineering students. It would be better to stress post graduate work for the few who will eventually go into research, for example.

4. As another way of achieving the very laudable objectives of a lengthened educational program for engineers, especially for mineral engineers, I submit a proposal made twenty-two years ago to the AIME. This proposal was for some form of co-operation with industry whereby the four-year graduate could enter an approved industrial training course at the successful conclusion of which, with proper regulations, the engineering school might confer the professional engineering degree (5).

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Mid-Winter Meeting of Engineering Drawing Division

Time: January 29–31, 1953.
Place: University of Nebraska, Lincoln, Nebraska.

A three day session of technical programs and inspection trips which will include technical papers and panel discussions by teachers of engineering drawing and men from industry. Inspection trips will include the Elgin Watch Company and Boy's Town. Detailed programs will be mailed to members of the Engineering Drawing Division.

Developing a Combustion Laboratory

By J. H. POTTER

Professor of Mechanical Engineering, University of Illinois

SUMMARY

In mechanical engineering curricula, combustion has received less attention than it merits. This is particularly true of the experimental phases of the subject.

This paper reports upon a part of the development of a combustion laboratory at the University of Illinois. Six experiments are described in which such classic measurements as flame temperatures, flame velocities, and explosion pressures are made.

Most of the test installations were made up of components usually available as physics laboratory apparatus. This made possible a fairly wide coverage at minimum cost.

I. INTRODUCTION

Combustion has been either neglected or inadequately covered in most mechanical engineering curricula. In many courses, a brief review of combustion stoichiometry is followed by an equally short treatment of radiant heat transfer, and then attention is focused upon a largely empirical approach to the design of furnaces and combustion equipment.

Since World War II greater interest has been shown in the fundamental aspects of combustion. It is entirely possible that the development of this field may parallel that of fluid mechanics some twenty years ago as a "rediscovered" area in mechanical engineering.

At the University of Illinois two courses have been set up, one dealing primarily with fuels and furnaces, and the other slanted toward the fundamental phases of the combustion process itself. A laboratory has been built as a demonstration facility to supplement the theoretical work in this second course. Precision is not sought in the combustion experiments; the principal purpose has been to repeat classic experiments and to give the student some feeling for the order of magnitude of the quantity being measured. Such mechanical concepts as torque, inertia and acceleration are known and understood by the student. An appreciation of the properties of flames and of explosion phenomena should be equally important to the engineer.

II. EXPERIMENTAL FACILITIES

Six of the combustion laboratory experiments will be described: two on flame temperature, three on flame velocity, and one on the pressure rise accompanying a gaseous explosion. In some cases the experiments were made possible by interdepartment loans of apparatus; some of the equipment was built up from standard components normally available in a physics laboratory.

(*A*) *Flame Temperature by Spectral Line Reversal*

This technique, originally so modestly described by Fery (1),* has been widely accepted as a standard method for measuring the temperature of a luminous flame. It depends upon the assumption that thermal equilibrium exists in a flame, and that chemiluminesence is negligible. It is further assumed that Kirchhoff's law is satisfied, and that the brightness temperature of a ribbon filament lamp has,

* Numbers in parentheses refer to the bibliography at the end of the paper. Where two numbers are used, the second represents the page number.

at resonance, the true or black body temperature of the flame through which the filament is viewed.

In Fig. 1, apparatus is shown arranged for measuring the temperature of a Bunsen burner flame by the line-reversal method. A tungsten ribbon filament lamp, of the type used in amateur moving picture projectors, is indicated at the right. This lamp is energized from a six volt source and connected so that the input may be varied and measured. The shield to the left of the lamp may be omitted, although a metal sleeve with a narrow slit may be attached to the lamp to limit the height of the tungsten spectrum. The combustion chamber is made up from 3-inch pipe fittings and has openings to permit the passage of light from the lamp. The lenses "A" and "B" are arranged to bring the image of the lamp filament to a sharp focus on the slit of the spectroscope. The flame is colored with an alkali salt, usually sodium chloride or sodium hydroxide.

The salt may be introduced into the flame or into the line supplying air to the burner. In the flame itself, one may (a) spray an aqueous solution of the salt, or (b) salt crystals may be held above the burner top on a wire. The air-borne technique involves either (a) finely divided salt powder, or (b) salt ionized in an electric arc, or (c) salt vaporized in a heater. The latter method is shown in Fig. 1.

The observer sees in the spectroscope the continuous band spectrum of the tungsten lamp, upon which is superimposed the strong sodium doublet at 5890 Å and 5896 Å. If the brightness temperature of the lamp is below that of the flame, the sodium doublet appears as two bright yellow lines. These lines "reverse" or turn black when the lamp brightness temperature exceeds that of the flame. For the particular case when the flame is emitting as much energy at the 5890–96 Å wave lengths as it is absorbing from the lamp, neither the bright nor the reversed lines will be seen. At this optical balance point, the electrical input to the lamp is measured. The burner assembly is moved out of the way, and an optical pyrometer is sighted on the lamp through the lens "A". The pyrometer reading is corrected for the difference in effective wave lengths of the pyrometer screen and that of resonance radiation in the flame. The corrected brightness temperature of the lamp is then taken as the true temperature of the flame.

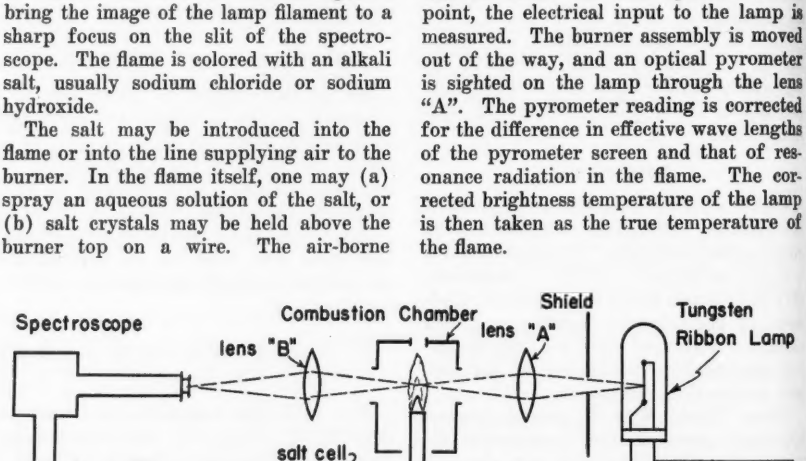

FIG. 1. Determination of Bunsen flame temperature by line reversal method. Temperature may be studied as a function of air-fuel ratio.

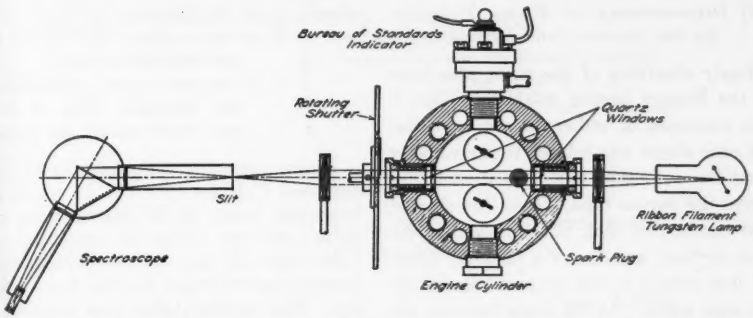

FIG. 2. Line reversal technique used to measure average temperature across diameter of cylinder of an internal combustion engine. Stroboscopic shutter relates temperature to crank angle.

The use of calibrated meters on the air and gas lines permits a study of the effect of variation of air-fuel ratio on the flame temperature. Control of the electric heater in the salt cell is effected by the variac.

(B) *Flame Temperature in an Internal Combustion Engine Cylinder by Spectral Line Reversal*

The measurement of the average flame temperature at a particular crank angle can be done by spectral line reversal. This method was successfully used by Hershey and Paton (2), and fortunately the test engine and many of the components were available for use in the combustion course.

The principal equipment is shown in Fig. 2. Because the maximum temperatures in a reciprocating gasoline engine are of the order of 4500° R., a special tungsten lamp was built with a "V" shaped filament. This device permitted a higher brightness temperature for a given filament temperature.

As the temperature varies from point to point during the engine cycle it is necessary to insert a stroboscopic shutter between the engine and the spectroscope. It may also be noted in Fig. 2 that the light path through the cylinder differs from that in the Bunsen flame of Fig. 1. The use of a parallel beam of light in the combustion chamber gives an average value of the flame temperature across this diameter. The use of the rotating shutter averages the temperature over a number of cycles so that the observer measures a temperature averaged both in time and in travel. An aqueous solution of sodium hydroxide is used, either as a finely divided spray or as a vapor from boiling liquid. In either case the sodium salt is introduced into the intake manifold.

The engine is a single cylinder water-cooled spark ignition type, suitably loaded. The particular engine used in this laboratory had a cylindrical combustion chamber which facilitated the location of the windows. Other recent installations have used constant speed units of the C. F. R. type. Quartz windows 7/32 inch thick and 3/4 inch in diameter are held in steel sleeves, which in turn are screwed in place in the cylinder against copper spark plug gaskets.

Pressure measurements are not essential, but a high speed Bureau of Standards indicator was part of the original test engine equipment.

Running at constant speed, the effects of air-fuel ratio and other standard engine variables may be traced in the temperature-crank angle or temperature-volume diagrams. P–V–T information may be obtained if the high speed indicator is used. Extensive chemical calculations may be made on the various equilibria involved.

(C) *Determination of Flame Velocities by the Bunsen Cone Method*

Early observers of the inner blue cone of the Bunsen burner established that it was composed of unburned gas, and that the cone shape was related to the velocity variation of the gas-oxidant mixture across the burner tube. Guoy (3) showed that combustion took place normal to the cone surface, and that the burning velocity was related to the mixture velocity by the cone angle. As the angle between the cone wall and the vertical axis of the burner varies, several measuring locations have been suggested. Noting that for laminar flow in a pipe the mean velocity is at a point 0.707 R from the centerline, this radius was used when the cone angles were measured. The flame velocity was then computed from:

$$V = U \sin \alpha$$

where: V is the burning velocity.
U is the average velocity of the gas-oxidant mixture.
α is the cone angle measured at the distance 0.707 R from the centerline of the burner.

A new approach was suggested by Garside and Culshaw (4) (5) in which the magnified image of the burner cone was traced, and the surface of revolution, divided into the rate of gas-oxidant flow, gave an overall value for the flame velocity. This method takes into account all of the variations of cone angle, and also allows for the fact that the bottom of the cone is not in contact with the top of the burner.

A modified Culshaw experiment is sketched in Fig. 3. An optical bench is used to hold the burner, lens system, and screen. These are arranged in line with a frosted lamp, and adjustments are made so that the top of the burner tube is focused on the glass screen, giving an

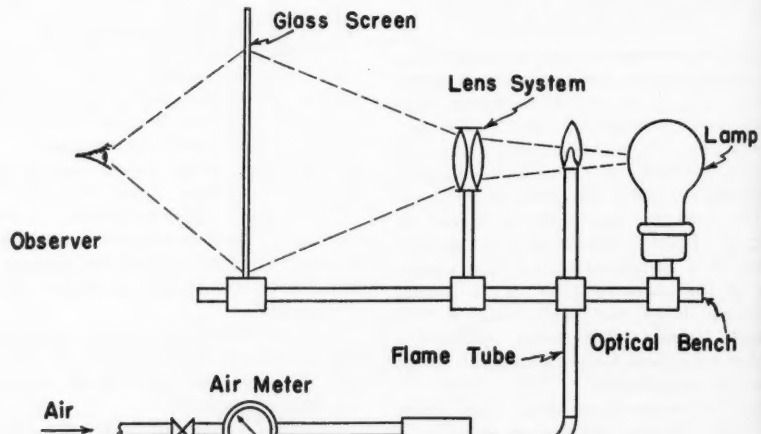

FIG. 3. Modified Garside and Culshaw experiment to determine flame velocity from Bunsen cone measurements. Air-gas ratio a controllable variable.

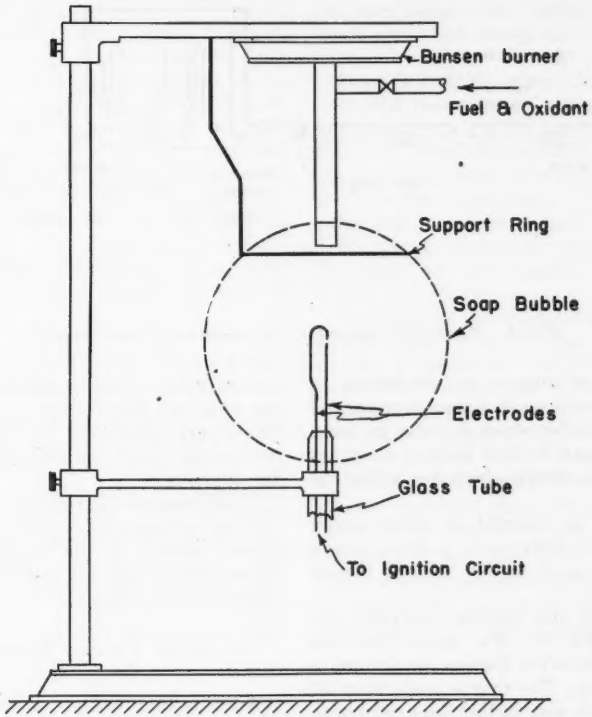

FIG. 4. Details of apparatus for blowing and supporting soap bubble in constant pressure bomb method for determining flame velocity.

image about six times as large as the tube. The lamp is turned off, and the enlarged image of the cone is traced on the glass screen. This may be done with tissue paper held against clear glass, or the glass itself may be frosted.

The tracing is divided by a number of horizontal lines and the volume of the figure of revolution swept out between each set is computed. These segmental volumes are then summed up and divided by the scale factor to obtain the actual area of the inner Bunsen cone.

Gas and air meters give a measure of the flow rate of the mixture, and the flame velocity is taken as the quotient of the flow rate by the cone area.

In this experiment a glass burner tube was used, having an internal diameter of 0.300 inches, and a length of 32 inches. No attempt was made to cool the burner tip nor to operate the combustion process at less than atmospheric pressure.

(*D*) *Flame Velocity Determination in the Isobaric Bomb*

Flame velocity may be measured by observing the rate of growth of a spherical flame front in an explosive mixture. The constant pressure bomb is well suited to this type of measurement, as only small quantities of the mixture are required. Also the mixture is initially at rest.

A widely used technique has been described by Jost (6–69) and is recounted in a number of the reports of the

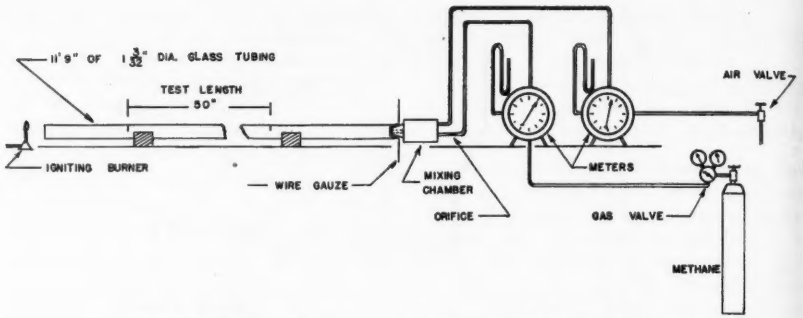

FIG. 5. Flame tube apparatus for measuring flame velocity.

N.A.C.A. It consists of introducing an explosive mixture into a soap solution and blowing a bubble about 3 inches in diameter. This can be done in such a manner as to include central electrodes within the bubble.

Ignition is designed to occur under photographic observation; a drum camera or a high speed motion picture camera may be used.

The bomb and ignition electrodes are shown in Fig. 4. The upper platform carries an inverted Bunsen burner and a support ring. The ring is made from 12 ga. steel wire and, in the plane normal to the paper, is bent to form a circle 2 inches in diameter. The lower support carries a glass tube through which the electrodes are threaded.

A soap film is drawn across the support ring by raising a dish of soap solution over the wire. The gas and oxidant are premixed in a small tank under a pressure of several inches of water. The air bleed on the Bunsen burner is sealed off, and the mixture is introduced slowly. Careful shaping of the electrodes makes it possible to blow the bubble over them. A battery and ignition coil circuit is used to ignite the charge.

A special drum camera was built for the laboratory. It consisted of a small synchronous motor directly connected to a small aluminum cylinder, the whole being enclosed in a black box equipped with a shutter and lens system. The drum camera gives a wedge shaped picture as the spherical flame front grows. From the picture dimensions and the synchronous motor speed, the flame velocity may be computed.

This technique has recently been refined (7) by substituting a thin transparent rubber balloon for the soap film. The newer method makes it possible to control moisture as a variable.

(*E*) *Flame Velocity Measured in a Long Tube*

A less refined method for measuring the velocity of a flame involves the timing of the flame front as it moves along a tube. Apparatus designed to do this is shown in Fig. 5.

Air and gas are separately metered and brought to a mixing chamber. A wire gauze screen covers the cork, connecting the tube and the mixing chamber, as a precaution against flashbacks.

In the particular test under consideration, the tube has an internal diameter of 1$\frac{3}{32}$ inches. This is below the 2 inch minimum suggested by writers in this field, who point out that the tube radius affects the flame speed in the smaller sizes. For this reason the test was considered less as an experiment than as a demonstration. In the latter sense, it was especially successful as it gave the student a real feeling for the magnitude of flame velocity under atmospheric conditions.

Two types of experiments were run on the apparatus. In the first, the tube was filled with an explosive mixture, the cork was removed, and the tube ignited at the far end. In the second, a steady flow of air-gas mixture was supplied and the flame front was obliged to move against this initial velocity of the mixture. In either case, the flame front was timed between two fixed points on the tube 50 inches apart. The flame velocities were computed from these data (6–65) and from the calculated initial velocities of the mixture.

(F) *Measurement of the Pressure Rise During Isometric Combustion*

Equipment for measuring the pressure rise during isometric combustion of a gaseous mixture is shown in Fig. 6. It parallels the work done by Clerk (8) some seventy years ago. The apparatus was built up largely of spare parts. The main vessel was an old annealing pot which, when covered and inverted, constituted a bomb of 366 cubic inch capacity. Three bosses were welded to the top, and were tapped for a filling connection, spark plug, and engine indicator respectively.

Through suitable valves, the bomb was connected to a vacuum pump so that it could be emptied of the products of combustion of the previous charge. The bomb was then filled with an explosive mixture and all of the valves closed. The indicator connection was opened, and the chronometric drum mechanism set in motion. The bomb was then ignited from an induction coil circuit.

The trace on the indicator card gave a pressure-time plot of the combustion process in the bomb. As a teaching device the experiment has some interesting aspects. The students were asked to estimate the temperature rise in the isometric bomb, and from this to make a refined adiabatic calculation including variable specific heats and dissociation. The temperature arrived at by the second approximation was then used to estimate the maximum pressure attainable. The spring for the engine indicator was selected after this calculation. The esti-

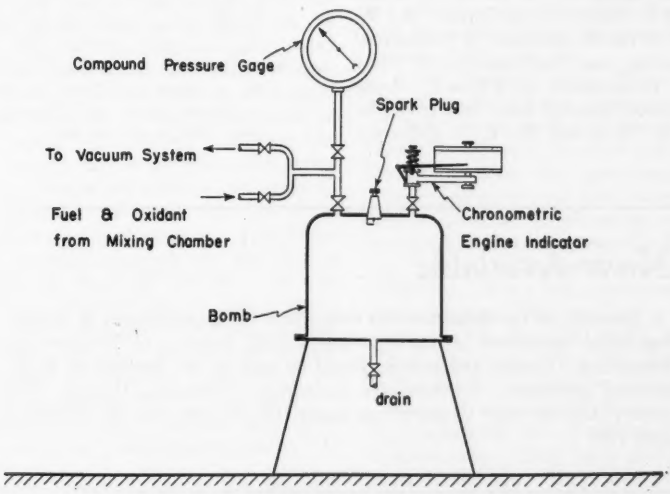

FIG. 6. Bomb equipped for measuring pressure-time relation during explosion of a gaseous mixture.

mated and measured values of the maximum pressure were compared in tabular form for several mixtures of air and hydrogen. The effect of mixture composition upon the rate of pressure rise was also noted.

III. Conclusions

This paper constitutes a progress report on the combustion laboratory. New experiments are in preparation, and several of the present techniques are being refined. The laboratory is intended as a teaching facility and is supplementary to the theoretical combustion course.

In general, the students have shown real enthusiasm for the type of work done in this laboratory. It has stimulated an interest in combustion research. Several students have later taken individual laboratory investigations in this field, and a few have written theses in the combustion area.

IV. Acknowledgments

The writer has had assistance from many students and staff members. For facilities, equipment or advice he wishes to thank Professors N. A. Parker and W. L. Hull of the Department of Mechanical Engineering, and Professor G. M. Almy of the Department of Physics. Long hours and substantial help were given by Dr. T. W. Price and Mr. R. B. Dillaway.

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Now Available . . .

Reprints of the **Report of the Committee on Improvement of Teaching** which appeared in the September, 1952 Journal of Engineering Education. Checks and orders should be sent to the Journal of Engineering Education, Northwestern University, Evanston, Illinois. The price is 10¢ per copy in quantities under 100, 05¢ per copy in quantities over 100.

Can Present Curricula in Industrial, Administrative, Management Engineering, Etc. Be Unified Under One Title?*

By WASHINGTON PLATT

Chairman, Dept. of Administrative Engineering, Syracuse University

The purpose of this paper is to define more clearly the field of usefulness covered by those Departments of Engineering called indiscriminately by such titles as Industrial, Administrative, Management Engineering, etc., and to suggest unification as to title.

It is NOT our purpose to propose a standardization of all curricula in this field any more than the curricula in Civil Engineering are now, or should be, standardized. Curricula in all branches of Engineering vary in emphasis at different universities in accordance with local opportunities and this is as it should be.

It is also NOT the purpose of this paper to attempt to draw sharp lines of distinction where no sharp lines in fact exist. In Chemical Engineering, for example, we would agree that a chemical engineer who was engaged in the design, construction or operation of equipment for carrying out industrial chemical reactions on a large scale was working in the typical field of the chemical engineer and that he was working in the field for which he was fitted by his education better than was any other kind of engineer. However, we admit freely that such activities grade imperceptibly in Chemical Engineering research into those of the pure chemist; and in construction and operation into those of the civil or mechanical engineer. If we can define the *typical fields of usefulness* the borderline cases need not worry us.

In what follows, "Industrial Engineering" will be used for the sake of brevity to cover the general field usually included under Industrial, Administrative, Management Engineering and similar titles.

Comparison with Chemical Engineering

The general development of Chemical Engineering as a well recognized field of Engineering will throw light on the present situation as to Industrial Engineering and the opportunities for overcoming our present difficulties.

About 30 years ago, David Wesson, then President of the American Institute of Chemical Engineers, stated that in the minds of many, a chemical engineer was the combination of a poor chemist with a poor engineer; and that many believed that a Chemical Engineering curriculum consisted of almost any miscellaneous mixture of a little Chemistry and a little Engineering. In my own experience when it was suggested that we hire a chemical engineer, the question would be asked, "Why don't you hire a *real* chemist?" or "Why don't you hire a *real* engineer?"

Chemical engineers were not discouraged by this general lack of understanding and appreciation. They have justified their place in the sun. They have proven that there are some activities that they can carry out better than any chemist and

* Paper presented before the Regional Meeting of the A.S.E.E., Buffalo, N. Y., October 14, 1950.

better than any other kind of engineer.

Like Chemical Engineering 30 years ago, I should say that few employers or others understand the present typical field of usefulness of Industrial Engineering. Many consider that the industrial engineer is a combination of a poor accountant with a poor engineer. They feel that the Industrial Engineering curriculum has no inherent unifying core; but consists of a miscellaneous three part mixture of engineering, personnel management and accounting.

Present Confusion in Titles

In the just mentioned ways, I am convinced that Industrial Engineering stands now just where Chemical Engineering stood 30 years ago.

In one important respect we are in a much worse position than the chemical engineer of 30 years ago. Chemical Engineering was never widely known by any other name. The chemical engineers had a big job explaining to all concerned what Chemical Engineering was, but they had only *one name* to explain. In the general field of Industrial Engineering we find several names covering exactly the same field and several other names in adjacent fields or which sound much the same.

For example, the ECPD (1948) accredits 19 curricula under the heading of Industrial Engineering. Of these, 11 use the title "Industrial Engineering"; 5, "Administrative Engineering"; while others use: "Engineering and Business Administration" (Harvard); "Business and Engineering Administration" (MIT); "Management Engineering" (RPI).

Outiside of these accredited Engineering courses we find names which sound at least superficially confusing such as Departments of "Industrial Administration" (Yale) and Colleges of "Business Administration" (Syracuse).

Under these circumstances it is not surprising that we are confused among ourselves and that we leave the public and our prospective employers even more confused.

What then is the field of usefulness of Industrial Engineering?

Industrial Engineering in Current Industry

First based upon current practices in industry. In 1947 Andrews wrote a Master's thesis on "A Study of Industrial Engineering Practices based on a Survey of Industry in the Syracuse Area" (1). If we accept the Syracuse Area as a reasonably fair sample we have here some light on what industry currently thinks Industrial Engineering is and ought to be.

The situation as found by Andrews is shown in the following table which shows what Industrial Engineering activities are practiced in current industry and under what departments.

Industrial Engineering in Current Curricula

On the other hand we have a valuable recent study by F. H. Thomas "Industrial Engineering—What Is It?" (2) showing what American Universities are currently offering under this heading. Nineteen Colleges of Engineering teach this branch of Engineering under the following titles:

Industrial Engineering—12
Administrative Engineering—3
Management Engineering—2
Business and Engineering Admin.—1
Option in other curricula—1

In deciding what should be included in Industrial Engineering curricula we need not be limited by current practices in industry. The universities should be a jump ahead of industry. They should exercise real leadership in finding useful industrial applications of the latest scientific and engineering developments.

Industrial Engineering Defined

It has been said that Engineering deals with

Materials, Methods, Men and Money
based upon Mathematics and
Physical Sciences

TABLE I

From Andrews, loc. cit.

Industrial Engineering Activities	Department to Which Assigned														
	Industrial Engineering Dept.	Production Engineering Dept.	Plant Engineering Dept.	Standards & Methods Dept. & Time Study Dept.	Production Control Dept.	Quality Control Dept.	Inspection Dept.	Planning Dept.	Wage & Rate Dept.	Safety Dept.	Personnel Dept.	Accounting & Comptroller	Cost Dept.	Other Depts., Individuals, or not specified	Total number of plants answering
A. Operator and Foreman training (formal or classroom)											6			18*	24
B. Preparation of Operation Sheets	3	1	7	12*	1			1					1	7	33
C. Methods and Motion Study	6	2	1	19*	1			1					1	6	34
D. Machine Loading	5	3	2	2	11*			3					1	6	33
E. Standard Machine Data Development	4	2	4	7*									2	6	25
F. Standard Time Study Data for Synthetic Rates	6	2	1	15*	1								2	3	30
G. Time Studies	7	2	1	19*									2	4	35
H. Actual Rate Administration	4	2		4					3		5		2	16*	36
I. Job Rating	5	2		5					4		7		2	11	36
J. Merit Rating	2	1			1				3		7		2	16*	32
K. Costs and Estimating	2	2	2	6	1			1				9	14*	5	42
L. Plant Layouts	2	2	17*	6										11	38
M. Production Control		4	1		20*			8						7	40
N. Quality Control		3	2		1	7	12*	1						8	34
O. Safety			3		1					11	13*			8	36
P. Planning and Scheduling		2	1	1	18*			7						10	39
Q. Standard Practice Bulletins	2	1	2	3							1	1		11*	21
R. Plant-wide Organization Charts	1								1		2	1		18*	23
S. Budget Control	2		1	1								15*	1	12	32

* Indicates the Department to which the activity is assigned in the greatest number of plants. 8/11/47 by DRA.

For M.E.'s, E.E.'s, C.E.'s and Ch.E.'s, the priority is in the order just given.

For Industrial Engineers the priority is:

Men, Methods, Money, Materials
based upon Mathematics,
Physical and Social Sciences

Briefly, an industrial engineer has first of all a reliable foundation in Engineering. He applies this engineering knowledge to manufacturing, or better, to the *coordination* of manufacturing.

Doctors of medicine have many specialties, but their whole medical course is

unified by their study of the human body and its interrelationships. So Industrial Engineering activities are of many kinds, but they all center around the applications of Engineering to the industrial organization, particularly to the manufacturing department. Industrial Engineering is for 9 out of 10 the Engineering of Manufacturing.

See also Goring (3).

Under typical conditions in the ideal factory the civil engineer designs and constructs the building itself, but the industrial engineer is responsible for Plant Layout including the location of machinery, working space, conveyors, storage space, etc.

The mechanical or electrical engineer is responsible for the design, construction and operation of the various pieces of mechanical or electrical equipment. However, the industrial engineer is responsible for integrating all pieces of equipment with the labor, raw material, conveyors, storage facilities, etc., into a streamlined, well-balanced, efficient, over-all manufacturing operation.

The M.E., E.E., C.E. or Ch.E. may consider principally the technical side of engineering, while the industrial engineer usually has a human being in the picture. The human factor and the dollar sign enter into most of his equations. Therein lies the chief difficulty, and also the chief glory of Industrial Engineering.

It may be said that a mechanical engineer is interested in a machine which is run by a human being; whereas an industrial engineer is interested in a human being who happens to be running a machine. It is significant that one of the typical studies of mechanical engineers is Kinematics, analyzing the motions of parts of machines, while a typical study for industrial engineers is Motion and Time Study which includes analyzing the motions of parts of human beings.

The branch of Industrial Engineering so far described concerns engineering problems which occur mostly within the four walls of a factory. Typical subjects are:

Factory Layout
Methods Engineering
Production Planning and Control
Quality Control
Motion and Time Study
Safety Engineering
Personnel Management
Employee Training

There is also a branch of engineering which is concerned with engineering surveys, top management planning, and engineering investigations of the kind made by consulting engineers for financial purposes. Problems attacked include those of plant location, industrial reorganization, industrial expansion, etc. University courses helpful in solving these problems include those in economic geography, population trends, transportation, business cycles, etc. It will be seen that many of these problems and their answers occur outside of the walls of a single factory.

This is a field of importance, but of limited numbers, compared with the enormous numbers engaged in the Engineering of Manufacturing. Those firms or companies having such activities usually assign their more mature engineers to such work, since experience and judgment are so essential. Few colleges of engineering emphasize such activities for their undergraduate curricula; though in most engineering colleges which are part of a large university, an undergraduate industrial engineer with sufficient electives or a graduate engineering student could easily prepare himself for such work by electing the proper courses in other colleges of the university.

Some few use "Industrial Engineering" for the Engineering of Manufacturing and the term "Administrative Engineering" to cover Engineering Surveys and Top Management Planning. This distinction is not generally recognized either in education or in industry. The desirability of the continued use of both titles is open to serious question.

Such surveys, planning and investigations can usually best be carried out by engineers because the engineering prob-

lems are often of fundamental importance, and are apt to be overlooked by those without an engineering background. It is believed that these activities can properly be included under the general title of "Industrial Engineering" along with the activities more intimately connected with Manufacturing proper. This practice is followed in the School of Engineering at Columbia University, for example, where considerable emphasis is put upon Engineering Surveys, yet this activity is included under the general title of Industrial Engineering. Where surveys and industrial investigations are concerned primarily with questions of accounting, law or finance, the field is not properly engineering at all. It should not have a quasi engineering title, but should be called frankly Business Administration.

Selection of a Title

In the selection of a title every consideration of this field known to the present author gives preference to Industrial Engineering over other possible names. For example, ECPD uses this general title for the Division to be represented on its General Council. The engineering society in this field is known as the American Institute of Industrial Engineers. The excellent article "What's New in Industrial Engineering?" (4) states that out of 28 Universities listed as giving degrees in this general field, 13 gave the degree in Industrial Engineering with the nearest competitor 4 in Engineering and Business Administration.

Several corporations such as Bethlehem Steel, Eastman Kodak, etc., have Departments of Industrial Engineering. Very few designate their departments in this field as Management or Administrative Engineering or one of the similar titles found in Universities for Departments in this area.

Rightly or wrongly, Industrial Engineering is preferred by many in industry as having a down-to-earth flavor, whereas Administrative Engineering suggests the "high hat" attitude. Some representatives of industry have feared that administrative engineers might object to getting their hands dirty. It is a fact that in Engineering Placement one receives ten requests for industrial engineers to every one for an administrative or management engineer.

The title adopted for this department of engineering should be short and simple, corresponding to the short, direct titles for Civil, Mechanical, Electrical Engineering, etc. Such simple titles are preferable to "Business and Engineering Administration," for example. In general, "Administration" or "Administrative" are undesirable words in the title. Titles containing these words are often confused with those of colleges of Business Administration.

The preponderance is therefore found to be overwhelmingly in favor of the term "Industrial Engineering." Is it not time that institutions using other titles did their part to eliminate the present confusion by conforming to the prevailing title, especially when the prevailing title is a pretty good one, however examined?

Conclusions

1. Those engineering activities now entitled Industrial, Administrative, Management Engineering, Business and Engineering Administration, etc., have a real unity and a definite field of usefulness in that all of these activities center around the industrial organization.

2. Such Engineering is well described as "Industrial Engineering"; that is, the application of engineering principles to industry, apart from those activities already covered by Civil, Mechanical, Electrical, and Chemical Engineering proper. In most of its aspects Industrial Engineering is the Engineering of Manufacturing. In its larger meaning it is the Engineering of the Industrial Organization as a whole.

3. Industrial Engineering problems usually emphasize Men and Money more than do other departments of Engineering. This adds to the difficulty and to the importance of this field. It is the distinction of Industrial Engineering that it specializes in the Human Side of Engineering.

4. One of the principal obstacles to a better understanding of this field has been the diversity of names by which the same field of Engineering has been called, and the border line curricula with superficially similar names which are not engineering at all, but which add to the confusion by their similarity of wording.

Recommendations

1. That the Department of Engineering concerned with the applications of Engineering to industrial concerns as a whole, and especially to the coordination of manufacturing with emphasis on the human and financial sides of Engineering, be unified under the title *Industrial Engineering.*

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College Notes

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Is the Traditional Program in College Mathematics Adequate for the Training of Prospective Engineers and Scientists?

By KENNETH L. NOBLE

Assistant Professor of Mathematics, University of Denver

At the present time, the college program of mathematical training for future engineers and scientists faces a double problem. It has the problem of extending its course work downward to complement the increasingly poor mathematical background of the high-school graduate as well as the need of enlarging its offerings to meet demands for the mathematics necessary in increasingly complex fields of science.

The quality and quantity of the high-school preparation in mathematics of students who intend to become engineers or scientists has long been a problem to college teachers of mathematics. Some students come to college with a good mathematical background, but many are poorly or inadequately prepared.

College teachers tend to place the blame for this unsatisfactory background on the high school. Is this a fair and reasonable criticism of most high schools? Another tendency is to feel that the student should not enter college to be trained as an engineer or scientist until he has the proper mathematical background. Is this attitude fair and reasonable in the case of many students?

In order to suggest an answer to these questions, suppose we consider some phases of the high-school situation at present, taking a large, over-all point of view.

Inasmuch as only a small portion of high-school graduates enter college to be trained as engineers or scientists, the preparation of students for the study of college mathematics is not a major objective in most high schools.

Some large high schools are able to offer enough work in mathematics to give an excellent background for college courses of study. The Denver high schools,[1] for example, offer four semesters of algebra, two of plane geometry, one of solid geometry, one of trigonometry and one of mathematical analysis.

Meager Offerings in Math

Since most of our high schools are small, their offerings in mathematics are meager and many students simply do not have the opportunity to acquire a good background. The small high school cannot afford, in the light of the number of students involved, an extended course of study in mathematics.

Although the guidance function of high schools is constantly improving, many students who wish to become engineers or scientists do not understand what abilities are needed for success in scientific work or what courses they should take in high school to prepare for that work. Also

[1] Denver Public Schools, *The Mathematical Program of the Denver Public Schools*, 1951.

students who could become good engineers or scientists may never be directed toward those fields.

In an address before the Committee on Secondary Schools of the American Society for Engineering Education, Evans, of the University of Maine, discussed the problem of high-school preparation:

> . . . representatives of prominent secondary schools told us that there was little hope that, by and large, our students would be better prepared in the future. . . . We shall see mathematics more interesting than effective, we shall see physics and chemistry more descriptive than mathematical, we shall see more time devoted to vocational subjects rather than to disciplinary drill in and mastery of those subjects which are more basic to a college education. . . . if a student knew when he entered as a [high-school] freshman that four years later he would be attempting to gain admission to an engineering school, he could do much to bolster his preparation. On the other hand, if many students who enter high school with definite plans to enter an engineering school knew more about the intellectual requirements necessary to successfully pursue an engineering education . . . they might wisely elect to try some other field. . . . Since the percentage of high-school graduates who go on to technical schools is very small, say between one and two per cent of the total, and perhaps ten or fifteen per cent of the total going to institutions of higher learning, we can hardly expect even the larger school to carry special facilities for this group.[2]

Percentage Enrollments

It is interesting to consider actual percentage enrollments in high-school courses which could contribute to a good mathematical background. Table 1 shows us that about one in six high-school students is enrolled in elementary algebra, one in nineteen in intermediate algebra, one in twelve in plane geometry, one in seventy in solid geometry, one in sixty in trigonometry, one in seventeen in chemistry and one in twenty-five in physics.

[2] W. S. Evans, "Let's Be a High School Freshman," *The Journal of Engineering Education*, **41**: 249, December, 1950.

TABLE 1

PERCENTAGE OF PUPILS ENROLLED IN CERTAIN HIGH-SCHOOL SUBJECTS IN ALL PUBLIC SECONDARY DAY SCHOOLS IN THE UNITED STATES, 1948–1949*

Subject	Percentage enrollment**
Elementary algebra	15.1
Intermediate algebra	5.4
Plane geometry	8.7
Solid geometry	1.4
Trigonometry	1.6
Chemistry	5.9
Physics	4.0

* Adapted from John R. Mayor, Editor, "What Is Going On in Your School," *The Mathematics Teacher*, **44**: 413, October, 1951.

** Based on a total enrollment of 6,907,833 pupils.

It may be fair and reasonable to criticize the efficiency of some high-school teaching of mathematics, but the criticism of inadequate offerings is not just. While there is much room for the improvement of guidance at the high-school level, it is not just to criticize the prospective engineer or scientist for lack of opportunity to obtain an adequate mathematical background.

College has Problem

Thus the college has the problem of bringing many freshmen up to a "state of readiness" for the usual mathematics courses which are a part of the training of engineers and scientists.

Concomitant with the small hope that freshmen entering college courses of study will have improving mathematical backgrounds is the fact that engineers and scientists need increasing amounts of ability in increasingly complex mathematical subjects.

Traditionally the future engineer or scientist has studied during the first two years at the college level the subject matter of college algebra, trigonometry, analytic geometry, differential calculus and integral calculus. In some schools,

electrical engineering students have also taken a beginning course in ordinary differential equations in the third year.

Pertinent to the need of an increasing background in mathematics, Bewley of Lehigh University states that:

> There are, however, certain electrical engineering courses which bring into play on genuine engineering problems the whole galaxy of undergraduate mathematics, and in addition point the way to the necessity for advanced study in mathematics as a necessary engineering tool. . . . The almost universally adopted undergraduate course in transients based on Heaviside's or the Laplace transform methods, require a substantial background in the theory of differential equations, gamma, error, and Bessel functions, certain theorems in algebra, Fourier series and integrals, and determinants; . . . .[3]

Bewley, in this same article, mentions other electrical engineering courses which require a knowledge of partial differential equations, operational calculus, series, boundary value problems, vector analysis, complex numbers, functions of a complex variable and others.

Along the same line, quoting Shanks of Purdue University:

> Consider the fact that a research engineer may be asked to tackle such difficult and diverse problems as the vibrations of nonlinear systems, the flow of viscous or compressible fluids, and the electromagnetic fields of complex configurations. Clearly it takes considerable mathematical maturity just to comprehend such problems.[4]

Daniels, in his book, *Mathematical Preparation for Physical Chemistry,* as early as 1928 included above calculus: ordinary and partial differential equations, infinite series, probability and various graphical methods of solving problems.

Not only must the college be able to improve the mathematical background of entering freshmen, but it must also be able to extend the training of engineering and science students beyond the usual courses in calculus.

Any solution of this problem must be considered in light of the total college curriculum for the engineering or scientific worker. For example, a feeling exists that such a student needs more training in English, social sciences and communications. The tendency is to add to, not subtract from subject matter.

Counseling Needed

Of great assistance in any solution would be the proper counseling of the high-school student. In this field the colleges could be of much help, particularly in acquainting the student with the abilities necessary for success in the engineering or scientific fields.

One possible type of solution would be the requiring of five years of training for the bachelor's degree. This would allow a two year pre-science training period followed by three years during which specialization could increase.

Another possible type of solution could be the giving of a broader course with less specialization during the four years and allow the needed specialization to come at the graduate level or through job experience after graduation.

It is realized that this problem is not universal but applies only to a portion of all college students. It probably does not apply equally to all engineering and physical science students. Nevertheless, the problem is crucial, particularly in view of maintaining a desirable reservoir of adequately trained scientific personnel.

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[3] L. V. Bewley, "Teaching Field Theory to Undergraduate Electrical Engineers," *The Journal of Engineering Education,* **40**: 532, May, 1950.

[4] M. E. Shanks, "Mathematics for Engineers," *The Journal of Engineering Education,* **41**: 308, January, 1951.

4. One of the principal obstacles to a better understanding of this field has been the diversity of names by which the same field of Engineering has been called, and the border line curricula with superficially similar names which are not engineering at all, but which add to the confusion by their similarity of wording.

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students who could become good engineers or scientists may never be directed toward those fields.

In an address before the Committee on Secondary Schools of the American Society for Engineering Education, Evans, of the University of Maine, discussed the problem of high-school preparation:

> . . . representatives of prominent secondary schools told us that there was little hope that, by and large, our students would be better prepared in the future. . . . We shall see mathematics more interesting than effective, we shall see physics and chemistry more descriptive than mathematical, we shall see more time devoted to vocational subjects rather than to disciplinary drill in and mastery of those subjects which are more basic to a college education. . . . if a student knew when he entered as a [high-school] freshman that four years later he would be attempting to gain admission to an engineering school, he could do much to bolster his preparation. On the other hand, if many students who enter high school with definite plans to enter an engineering school knew more about the intellectual requirements necessary to successfully pursue an engineering education . . . they might wisely elect to try some other field. . . . Since the percentage of high-school graduates who go on to technical schools is very small, say between one and two per cent of the total, and perhaps ten or fifteen per cent of the total going to institutions of higher learning, we can hardly expect even the larger school to carry special facilities for this group.[2]

Percentage Enrollments

It is interesting to consider actual percentage enrollments in high-school courses which could contribute to a good mathematical background. Table 1 shows us that about one in six high-school students is enrolled in elementary algebra, one in nineteen in intermediate algebra, one in twelve in plane geometry, one in seventy in solid geometry, one in sixty in trigonometry, one in seventeen in chemistry and one in twenty-five in physics.

[2] W. S. Evans, "Let's Be a High School Freshman," *The Journal of Engineering Education*, **41**: 249, December, 1950.

TABLE 1

PERCENTAGE OF PUPILS ENROLLED IN CERTAIN HIGH-SCHOOL SUBJECTS IN ALL PUBLIC SECONDARY DAY SCHOOLS IN THE UNITED STATES, 1948–1949*

Subject	Percentage enrollment**
Elementary algebra	15.1
Intermediate algebra	5.4
Plane geometry	8.7
Solid geometry	1.4
Trigonometry	1.6
Chemistry	5.9
Physics	4.0

* Adapted from John R. Mayor, Editor, "What Is Going On in Your School," *The Mathematics Teacher*, **44**: 413, October, 1951.

** Based on a total enrollment of 6,907,833 pupils.

It may be fair and reasonable to criticize the efficiency of some high-school teaching of mathematics, but the criticism of inadequate offerings is not just. While there is much room for the improvement of guidance at the high-school level, it is not just to criticize the prospective engineer or scientist for lack of opportunity to obtain an adequate mathematical background.

College has Problem

Thus the college has the problem of bringing many freshmen up to a "state of readiness" for the usual mathematics courses which are a part of the training of engineers and scientists.

Concomitant with the small hope that freshmen entering college courses of study will have improving mathematical backgrounds is the fact that engineers and scientists need increasing amounts of ability in increasingly complex mathematical subjects.

Traditionally the future engineer or scientist has studied during the first two years at the college level the subject matter of college algebra, trigonometry, analytic geometry, differential calculus and integral calculus. In some schools,

electrical engineering students have also taken a beginning course in ordinary differential equations in the third year.

Pertinent to the need of an increasing background in mathematics, Bewley of Lehigh University states that:

> There are, however, certain electrical engineering courses which bring into play on genuine engineering problems the whole galaxy of undergraduate mathematics, and in addition point the way to the necessity for advanced study in mathematics as a necessary engineering tool. . . . The almost universally adopted undergraduate course in transients based on Heaviside's or the Laplace transform methods, require a substantial background in the theory of differential equations, gamma, error, and Bessel functions, certain theorems in algebra, Fourier series and integrals, and determinants; . . . .[3]

Bewley, in this same article, mentions other electrical engineering courses which require a knowledge of partial differential equations, operational calculus, series, boundary value problems, vector analysis, complex numbers, functions of a complex variable and others.

Along the same line, quoting Shanks of Purdue University:

> Consider the fact that a research engineer may be asked to tackle such difficult and diverse problems as the vibrations of nonlinear systems, the flow of viscous or compressible fluids, and the electromagnetic fields of complex configurations. Clearly it takes considerable mathematical maturity just to comprehend such problems.[4]

Daniels, in his book, *Mathematical Preparation for Physical Chemistry,* as early as 1928 included above calculus: ordinary and partial differential equations, infinite series, probability and various graphical methods of solving problems.

Not only must the college be able to improve the mathematical background of entering freshmen, but it must also be able to extend the training of engineering and science students beyond the usual courses in calculus.

Any solution of this problem must be considered in light of the total college curriculum for the engineering or scientific worker. For example, a feeling exists that such a student needs more training in English, social sciences and communications. The tendency is to add to, not subtract from subject matter.

Counseling Needed

Of great assistance in any solution would be the proper counseling of the high-school student. In this field the colleges could be of much help, particularly in acquainting the student with the abilities necessary for success in the engineering or scientific fields.

One possible type of solution would be the requiring of five years of training for the bachelor's degree. This would allow a two year pre-science training period followed by three years during which specialization could increase.

Another possible type of solution could be the giving of a broader course with less specialization during the four years and allow the needed specialization to come at the graduate level or through job experience after graduation.

It is realized that this problem is not universal but applies only to a portion of all college students. It probably does not apply equally to all engineering and physical science students. Nevertheless, the problem is crucial, particularly in view of maintaining a desirable reservoir of adequately trained scientific personnel.

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[3] L. V. Bewley, "Teaching Field Theory to Undergraduate Electrical Engineers," *The Journal of Engineering Education,* **40**: 532, May, 1950.

[4] M. E. Shanks, "Mathematics for Engineers," *The Journal of Engineering Education,* **41**: 308, January, 1951.

TIMELY TIPS

Right Triangles with Integral Sides

By F. C. BRAGG

Associate Professor of Engineering Drawing and Mechanics,
Georgia Institute of Technology

(Papers submitted for TIMELY TIPS *should not exceed 3 pages of typewritten, double-spaced material, including any mathematical formulas, and should contain not more than 1 illustrations.)*

It is well known that there are certain triangles, whose sides are integral numbers, such as 3, 4, and 5, which are right triangles. However, relatively few of these many number combinations which will designate the sides of right triangles are available to the teaching profession.

To correct this situation, the attached table gives 90 such combinations of which 76 represent independent or prime relationships, while the other 14 items are multiples of the independent or prime combinations.

This table was derived as follows:

Let the three sides of a triangle be

$$A = 2k^2 + 2kn + n^2$$
$$B = 2k^2 + 2kn$$
$$C = 2kn + n^2$$

TABLE OF RIGHT TRIANGLES WITH INTEGRAL SIDES

	$n=1$	$n=3$	$n=5$	$n=7$	$n=9$	$n=11$	$n=13$	$n=15$	$n=17$
$k=1$	3 4 5	15 8 17	35 12 37	63 16 65	99 20 101	143 24 145	195 28 197	255 32 257	323 36 325
$k=2$	5 12 13	21 20 29	45 28 53	77 36 85	117 44 125	165 52 173	221 60 229	285 68 293	357 76 365
$k=3$	7 24 25	27 36 45 (9)	55 48 73	91 60 109	135 72 153 (9)	187 84 205	247 96 265	315 108 333 (9)	391 120 409
$k=4$	9 40 41	33 56 65	65 72 97	105 88 137	153 104 185	209 120 241	273 136 305	345 152 377	425 168 457
$k=5$	11 60 61	39 80 89	75 100 125 (25)	119 120 169	171 140 221	231 160 281	299 180 349	375 200 425 (25)	459 220 509
$k=6$	13 84 85	45 108 117 (9)	85 132 157	133 156 205	189 180 261 (9)	253 204 325	325 228 397	405 252 477 (9)	493 276 565
$k=7$	15 112 113	51 140 149	95 168 193	147 196 245	207 224 305	275 252 373	351 280 449	435 308 553	527 336 625
$k=8$	17 144 145	57 176 185	105 208 233	161 240 289	225 272 353	297 304 425	377 336 505	465 368 593	561 400 689
$k=9$	19 180 181	63 216 225 (9)	115 252 277	175 288 337	243 324 405 (9)	319 360 481	403 396 565	495 432 657 (9)	595 468 757
$k=10$	21 220 221	69 260 269	125 300 325 (25)	189 340 389	261 380 461	341 420 541	429 460 629	525 500 725 (25)	629 540 829

with k and n any numbers greater than zero. Then the triangle will be a right triangle and, if k and n are integers, then the sides will also be integral numbers. It should be further noted, when even integral numbers are used for n, then the resultant triangles are not independent or prime.

In the table, columns represent triangles obtained by substituting for k integral values from 1 to 10 inclusive, and the rows give triangles found by using odd integral values from 1 to 17 inclusive for n. The 76 independent or prime combinations are indicated by three numbers showing the values for the three sides of the right triangle, while the 14 other combinations have fourth number in parentheses, which, when divided into each value, will give the basic independent combination to which the dependent combination is related. Expansion of the table may be accomplished by a further substitution of values for k and n with either one or both numbers greater than those used in the table.

Reserve this date . . . .

June 22-26, 1953

ANNUAL MEETING

UNIVERSITY OF FLORIDA

GAINESVILLE, FLORIDA

Report of Treasurer, 1951–1952

Ernest C. Davies
Certified Public Accountant

August 1, 1952

Mr. C. L. Skelley
Technical Book Department
Macmillan Company
60 Fifth Avenue
New York 11, New York

Dear Mr. Skelley:

In accordance with your instructions we have examined the accounts and records of the American Society for Engineering Education for the year ending June 30, 1952 and submit herewith the following statements prepared therefrom:

Exhibit I—Comparative Balance Sheets
Exhibit II—Comparative Statements of Changes in Funds
Exhibit III—Comparative Statements of Income and Expense
Exhibit IV—Comparative Statements of Receipts and Disbursements

In connection with the statements as of June 30, 1952, we examined and tested the accounting records, traced the receipts as recorded to deposit, checked the disbursements, counted the securities on hand, and secured direct confirmation for all funds or securities in the hands of outside parties. Our examination was made in accordance with generally accepted auditing standards and included all procedures which we considered necessary in the circumstances.

In accordance with a resolution of the Board of Directors, the excess of ECRC receipts and budgeted expenditure over ECRC disbursements has been transferred to ECRC reserve.

Also Furniture and Fixtures purchased have been charged against revenue in order to comply with the Board of Directors resolution to carry Furniture and Fixtures at the nominal value of $1.00.

In our opinion these statements fairly present the position of the Society at June 30, 1952 and the results of its operations for the period then ended.

Yours truly,

ERNEST C. DAVIES
Certified Public Accountant

AMERICAN SOCIETY FOR ENGINEERING EDUCATION
COMPARATIVE BALANCE SHEETS

EXHIBIT I

	June 30, 1951	June 30, 1952
Assets		
Current Fund:		
Cash in State Bank and Trust Co.	$21,319.53	$29,627.7
Petty Cash	300.00	300.0
U. S. Government Bonds—Series G	30,700.00	30,700.0
	$52,391.53	$60,627.7

Life Membership Fund:		
Cash	183.11	209.95
U. S. Government Bonds—Series G	1,000.00	1,000.00
	$ 1,183.11	$ 1,209.95
B. J. Lamme Fund:		
Cash—Checking	230.46	163.08
Principal Cash in Hands of Trustee	9.00	9.00
Securities and Mortgages	5,132.73	5,132.73
	$ 5,372.19	$ 5,304.81
Accounts Receivable:		
Advertising	1,560.90	2,747.44
Dues	1,275.00	1,800.00
Westinghouse Educational Foundation	83.91	323.69
Income Cash in Hands of Lamme Trustee	121.46	133.86
	$ 3,041.27	$ 5,004.99
Prepaid Travel Expense	—	425.00
Inventory	1.00	1.00
Furniture and Fixtures	1.00	1.00
Total Assets	$61,990.10	$72,574.51
Liabilities and Capital		
Current Liabilities:		
Accounts Payable—Publications	16.65	—
Other Accruals	1,453.54	407.88
	$ 1,470.19	$ 407.88
Prepaid Membership Dues	$ 1,706.78	$ 508.25
Funds (Per Exhibit II):		
Life Membership Fund	$ 1,183.11	$ 1,209.95
B. J. Lamme Fund	5,372.19	5,304.81
Teaching Aids Fund	4,362.50	6,975.12
	$10,917.80	$13,489.88
General Fund:		
Reserve for ECRC	—	$ 6,004.69
Reserve for Special Projects	$ 6,056.62	6,056.62
Unappropriated Surplus	41,838.71	46,107.19
	$47,895.33	$58,168.50
Total Liabilities and Capital	$61,990.10	$72,574.51

COMPARATIVE STATEMENT OF CHANGES IN FUNDS

EXHIBIT II

	12 Months Ended June 30, 1951	12 Months Ended June 30, 1952
Life Membership Fund		
Balance at Beginning of Period	$ 1,155.87	$ 1,183.11
Add: Contribution to Fund	25.00	25.00
Interest on Fund	2.24	1.84
Balance at End of Period	$ 1,183.11	$ 1,209.95
B. J. Lamme Fund		
Balance at Beginning of Period	$ 5,418.66	$ 5,372.19
Add: Additions to Fund	126.04	228.62
	$ 5,544.70	$ 5,600.81
Less: Award and Expenses	172.51	296.00
	$ 5,372.19	$ 5,304.81
General Education Board		
Balance at Beginning of Period	$ 9,950.00	—
Add: Refund received from SE Section	3,279.02	—
	$13,229.02	—
Less: Refund Made to Gen. Educ. Board	$13,229.02	—
Balance at End of Period	—	
Teaching Aids Fund		
Balance at Beginning of Period	—	$ 4,362.50
Add: Income of Fund	$ 4,570.00	3,605.00
	$ 4,570.00	$ 7,967.50
Less: Expenses of Fund	207.50	992.38
Balance at End of Period	$ 4,362.50	$ 6,975.12
Unappropriated Surplus		
Balance at Beginning of Period	$40,096.08	$41,838.71
Add: (See Notes to Financial Statements)		
Excess Expense over Income	(311.07)	
Transfer from ECRC Reserve	1,315.03	
Transfer from Special Projects	1,486.45	
Excess Income over Expense		$10,273.17
Transfer to ECRC Reserve		(6,004.69)
Net Addition	$ 2,490.41	$ 4,268.48
	$42,586.49	$46,107.19
Less: Write off of Furniture and Fixtures	$ 747.78	
Balance at End of Period	$41,838.71	$46,107.19

COMPARATIVE STATEMENT OF INCOME AND EXPENSE

EXHIBIT III

	12 Months Ended June 30, 1951	12 Months Ended June 30, 1952	Budget 1952–53
Income:			
Current Dues—Individual	$39,113.20	$39,719.28	$39,300
Institutional	6,661.00	8,105.00	9,600
Sale of Publications	2,257.24	2,069.32	2,000
Advertising	9,401.38	10,896.21	13,500
Interest on Government Bonds	792.50	792.50	780
ECRC	1,228.06	3,560.86	—
Income—B. J. Lamme Fund	.02	12.40	—
Refund from EJC	—	407.71	—
Miscellaneous	863.62	—	—
Total Income	$60,317.02	$65,563.28	$65,180
Expense:			
Annual Meeting Expense	$ 2,016.53	$ 2,214.34	$ 2,500
Cost of Publications	24,139.43	22,884.88	24,000
Committees and Conferences	1,153.57	658.22	1,300
Postage, Telephone, and Telegraph	1,416.98	1,565.83	1,600
Supplies and Sundry Printing	2,895.55	3,171.05	2,700
Office Expense	80.27	—	—
Expenses ECAC	1,630.66	1,126.99	2,200
Expenses ECRC	8,379.54	1,906.17	4,350
Officers' Travel Expense	1,694.64	2,365.99	2,000
Secretary's Travel Expense	1,007.73	1,878.71	1,950
President's Expense	460.87	—	500
Salaries	11,018.44	12,658.51	18,600
Bonding, Auditor's Fees, etc.	486.28	321.59	325
Retirement Emeritus	1,360.00	1,360.00	1,360
Dues—Am. Council on Education	100.00	100.00	200
Contribution ECPD	500.00	500.00	500
Miscellaneous	75.31	—	1,000
Special Projects*			
Purchase of Typewriters	291.45		
Purchase of Dictaphones		764.35	
N. Y. Times Reprint	615.71		
Committee on Improvement of Teaching	397.42	815.64	
Contribution EJC	407.71		
Additional Contribution ECPD	500.00		
Purchase of Mimeograph Machine		1,062.84	
Credit on IBM Typewriter		(65.00)	
	$60,628.09	$55,290.11	$65,085
Excess of Income over Expense		$10,273.17	
Excess of Expense over Income	311.07		
Transfer to (or from) ECRC Reserve	$ 2,801.48	$ 6,004.69**	
Balance to Surplus (to Exhibit II)	$ 2,490.41	$ 4,268.48	

* Per resolution of Executive Board, Furniture and Fixtures are to be carried at a nominal value of $1, and any purchases are to be charged as expense.

** This transfer includes income from ECRC publications and the unused budget of the ECRC. It was authorized by the Executive Board, June 25, 1952, in order to give the ECRC an adequate reserve fund to smooth out its fluctuations in expense from year to year.

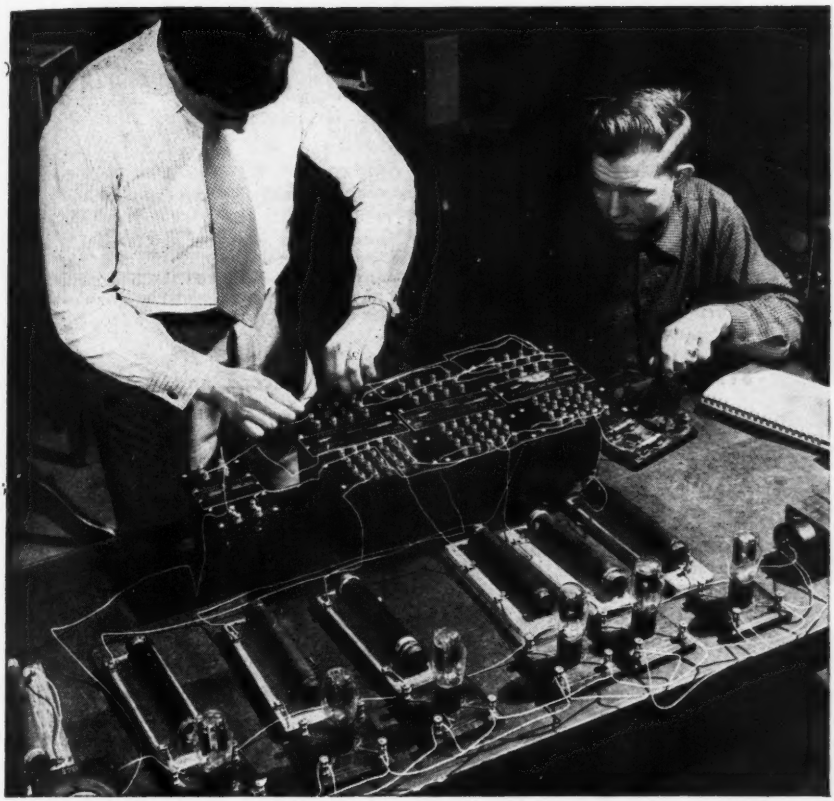
† The audit of Receipts and Disbursements (Exhibit IV) is available from the Secretary's office.

Section Meetings

Section	*Location of Meeting*	*Dates*	*Chairman of Section*
*Allegheny	West Virginia University		C. H. Cather, West Virginia University
Illinois-Indiana	Rose Polytechnic Institute	May, 16, 1953	H. A. Moench, Rose Polytechnic Institute
Kansas-Nebraska	University of Kansas	Oct. 24–25, 1952	M. A. Durland, Kansas State College
Michigan	Detroit Institute of Technology	May 9, 1953	C. C. Winn, Detroit Institute of Technology
Middle Atlantic	Manhattan College	December 6, 1952	W. B. Plank, Lafayette College
Missouri	Washington University	April 11, 1953	G. F. Branigan, University of Arkansas
National Capital Area	Catholic University of America	Oct. 7, 1952	L. K. Downing, Howard University
	Howard University	May 9, 1953	
	University of Maryland	Feb. 3, 1953	
New England	Worcester Polytechnic Institute	Oct. 18, 1952	E. T. Donovan, University of New Hampshire
North Midwest	Iowa State College	Oct. 3–4, 1952	S. J. Chamberlin, Iowa State College
*Ohio	University of Cincinnati	April, 1953	H. K. Justice, University of Cincinnati
*Pacific Northwest	Washington State College	Spring, 1953	J. P. Spielman, Washington State College
Pacific Southwest	California State Polytechnic College	Dec. 29–30, 1952	C. E. Cherry, College of Marin
*Rocky Mountain	University of Wyoming		C. A. Hutchinson, University of Colorado
*Southeastern	Louisiana State University	March, 1953	D. V. Terrell, University of Kentucky
Southwestern	University of New Mexico	April 3 & 4, 1953	M. L. Ray, University of Houston
Upper New York	Alfred University	October 10–11, 1952	R. M. Campbell, Alfred University

Members of the Society are welcome at all Section Meetings

* No Date Set.



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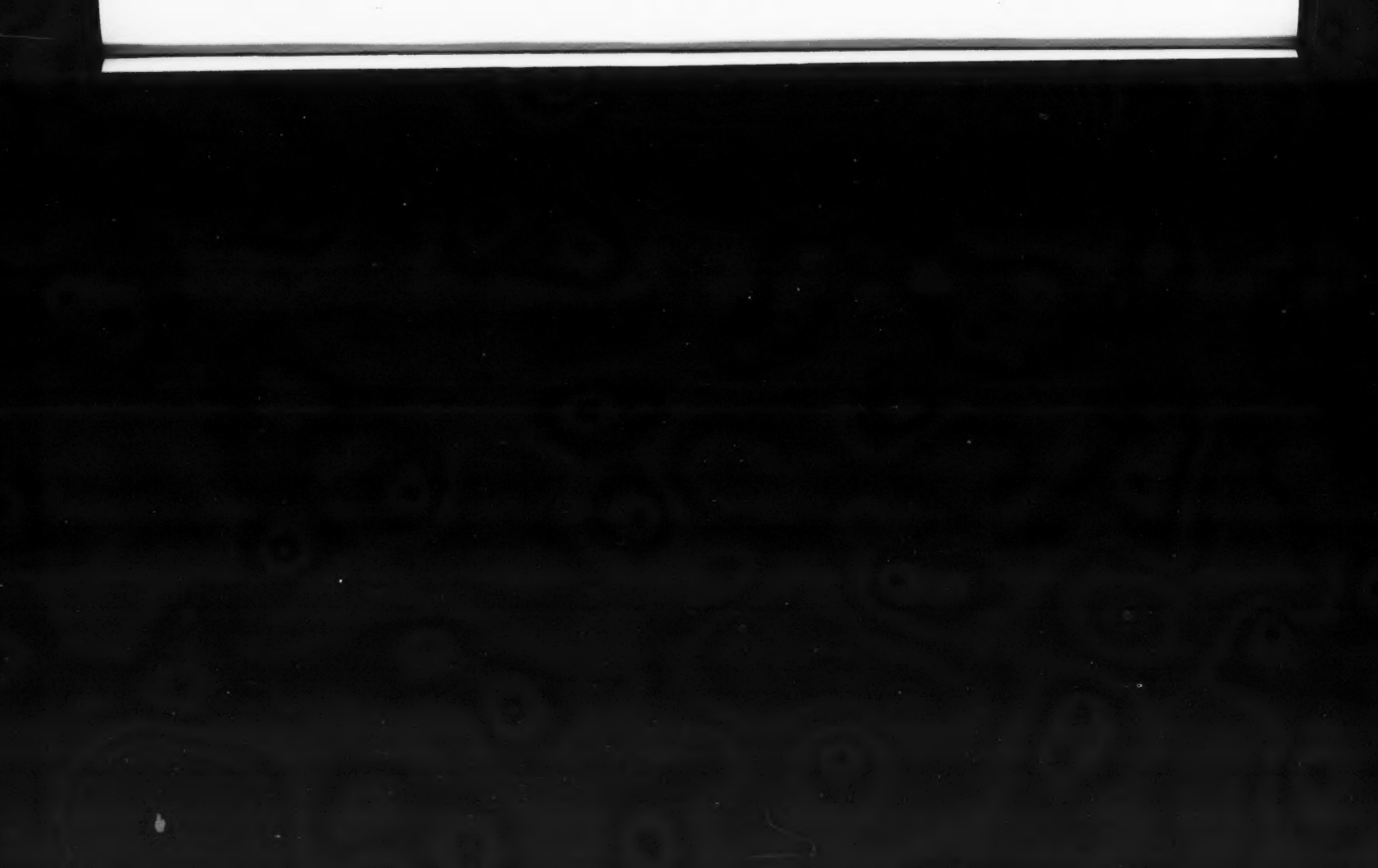

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